REMOVAL OF ALGAE FROM WATERS

A thesis submitted
In partial fulfilment of the requirements
for the Degree of

MASTER OF TECHNOLOGY

by

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to the

Department of Civil Engineering
Indian Institute of Technology, Kanpur

August 1969

CERTIFICATE

This is to certify that the present work has been done under my supervision and the work has not been submitted elsewhere for a degree.

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ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitudes to Professor A.V.S. Prabhakara Rao for his valuable suggestions, guidance and constant encouragement while carrying out the experiments and in writing this thesis.

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SYNOPSIS

This study presents experimental investigation on the removal of algae with a wide variety of algicides and coagulants. The present work aims at finding out the most suitable and economical algicides that can be used in practice. In Chlorella dominated water it is found that copper sulfate, which is mostly accepted algicides for controlling algae, is ineffective. Potassium permanganate a strong oxidising agent removes the algae to a greater degree than copper sulfate. It is also found that the optimum dose of proper coagulant reduces the dose of permanganate for the same removal of algae. Ferric chloride is found to be more efficient coagulant compared to alum. The experiments with chlorine reveal that it is effective in removal of algae but not as effective as potassium permanganate. Animal charcoal seems to be ineffective in algae removal and is the case with Iodine. Contact time which is an important parameter in the study seems to affect the removal of algae with algicides.

1. INTRODUCTION

Microbiological growths in natural waters became problematic due to tastes and odors contributed by them to the water and clogging effect on the sand filters resulting in short filter runs. Present methods of waste disposal are intensifying the nuisance organism problems in water supplies. Fertilizing materials such as sewage and organic wastes from milk plants, canneries, paper mills and fertilizer factories greatly increase the productivity of the waters and their crops of algae and other planicton organisms. Algae are a problem when they become abundant. It is apparent, therefore, that problems of algae will become more widespread and severe as our growing urban populations and industry continue to discharge their wastes into streams.

Huff (1) observed that the algae of water supplies are minute forms of plant life, often too small to be seen with the naked eye. In structure they rank among the simplest of plants, yet in conquest of the earth they have been preeminently successful. They are found in lakes and rivers, ditches, ponds, reservoirs, in fact wherever natural waters are exposed to the light. According to Palmer (2) the number and kinds of algae and other organisms which grow in surface waters depend on environmental conditions. In muddy streams such as the Missouri, turbidity limits light penetration sufficiently so

that fewer problems occur from algal growths. When impoundments are built in such a stream they create settling basins in which the water clears and algal growths develop, producing tastes and odors or other nuisance conditions. Pool size, shape, depth, amount of shore line, extent of shoal areas, character of the bottom, physiography and soils of the watershed, amount and rate of precipitation, sunlight and quality of the water are all factors influencing the growth of algae in a reservoir. Some species do not grow readily in the absence of bacteria, indicating that bacteria may produce some material needed by the algae.

Short filter runs at Detroit (3) during the winter and early spring have lasted as long as a month. The predominant species causing short runs has appeared to be Asterionella. Treatment during algal blooms has consisted of the use of alum in excess and excess costs have been as high as $ 15,000 per month during these periods. Some of the difficulties encountered in the water treatment plant by the presence of algae can be summarized as follows:

i) Living or dead algae clog the filters
ii) Taste and odor is imparted to the water by algae
iii) Algae in contact with submerged concrete blocks may cause complete disintegration of the concrete
iv) The growth of algae corrode the metal tanks and pipes and form pits

v) Some of the algae may also be toxic and growth of such forms in rivers and reservoirs, which are the source of drinking water is a matter of great importance.

Considerable attention is being paid to the control and removal of algae from natural waters. Identification and recording of algae concentration is essential because the measures taken for algal control depend upon the type and concentration of algae. It will not be an exaggeration to say that almost all surface waters are polluted to a greater or lesser extent. In tropical countries, because of the light and temperature algal growths are more abundant. In Kanpur the waterworks engineers are facing difficulties during summer months when the Ganges water carries a number of filter clogging algae. A survey of literature indicates that copper sulfate is one of the main chemicals used to control algal growths. There seems to be no definite work indicating copper sulfate as the best chemical for control of algae. A systematic study of the effect of various chemicals on removal of algae, it is felt, would yield valuable information in this problem.

1.2 Aim

To study the effects of various algicides, coagulants and other chemicals on the removal of algae from waters.

1.3 Scope

The studies were conducted with low and high concentrations of algae. Two different sources of water containing two different predominant groups of algae were used. In one source Chlorella was dominating and in second Anthrospira was dominant. For a systematic study many of the chemicals that are often used for controlling algae were used in this study, namely, copper sulfate, potassium permanganate, chlorine lime, animal charcoal, iodine and the coagulants used were alum and ferric chloride.

The pertinent literature on the subject are briefly presented in the following chapter.

2. LITERATURE

2.1 Taste and Odor Causing Algae

Generally unpleasant tastes and undesirable odors in waters are associated with each other because both are derived from the same source (4). However, iron, magnesium, sulfate, sodium sulfate and sodium chloride cause taste only. The causes of tastes and odors in water supply could be divided into two categories (i) natural and (ii) man made. Problems due to natural causes include algae, leaves and decaying vegetation. The second category includes problems due to pollution with sewage and industrial wastes. Algae are the most frequent offenders among the natural causes of tastes and odors. Almost every surface supply is likely to be with sufficient concentration of algal growth to cause objectionable odors (5). The cause of offensive odors may be due to particular kinds of algae as they die off, but on the whole, rarely taste and odor troubles are caused by living algae (6). Odors imparted by living algal growths are termed as "natural odors" to differentiate them from quite different and objectionable "odors of decomposition" caused by dying and decaying masses of algae (7).

Turre (8) classified distinctive odors, produced by algae, under three general terms: Aromatic, Grassy, and Fishy.

Aromatic odors are due, chiefly to, Diatoms. The strongest odor is produced by Asterionella. The other forms are Cyclotella, Diatoma, Meridion, Synedra and Tabellaria. Grassy odors are usually produced by blue green algae such as Anabaena, Aphanizomenon, Clthrocystis, Coelosphaerium and Cylindrospermum. Fishy odors are perhaps the most disagreeable odors detected in drinking water supply. Uroglena when abundantly present in water imparts a cod oliver odor. The other species which also produce fishy odors are Volvox, Eudorina and Pandorina. In Fig. 1, some odor causing algae are shown.

2.2 Algae Causing Filter Clogging

Damage is caused by excessive algae in a number of ways. The seasonal havoc they cause by interfering with filtration is only too well-known. Rapid sand filters which might, under normal conditions, operate for 75 to 100 hours between washes sometimes have filter runs reduced to 2 hours (9). Diatoms such as Synedra, Melosira, Asterionella; the yellow brown flagellate Mallomonas, the green flagellates cChlamydomonas, Platymonas, and Euglena, the olive green flagellates Cryptomonas; and occasionally the green non-flagellated algae such as Dictyosphaerum, are responsible for filter clogging and they may support an active growth on the filters (10). The algae growing on the filters release oxygen during photosynthesis and keeps the filter aerobic. By diatoms clogging of the filter is speeded up because they have rigid cell walls. Some of the filter clogging algae are shown in Fig. 2.

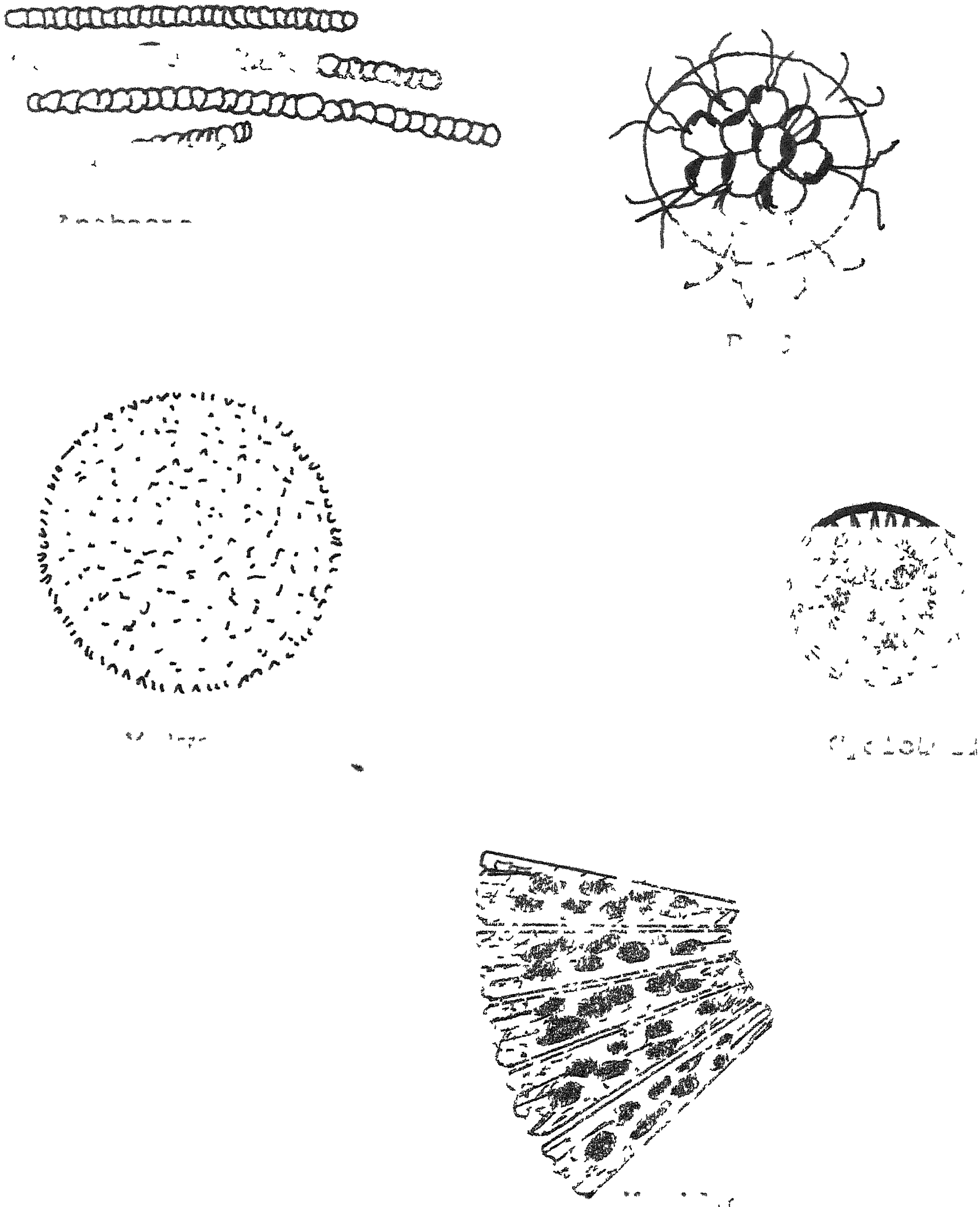
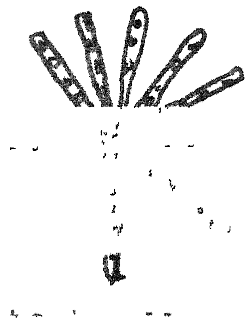
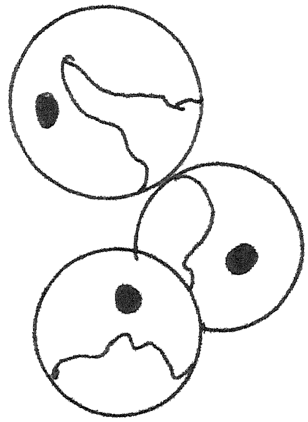


Fig. 1 Taste and odor causing Algae





Chlorella

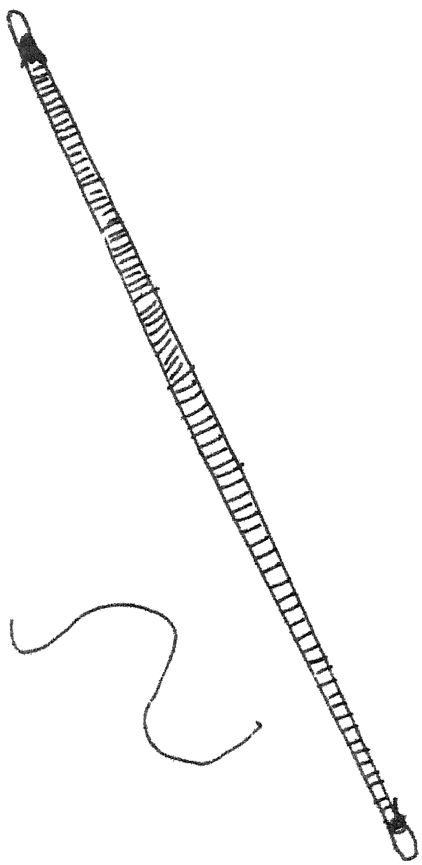


Fig. Filter [illegible] lgae

2.3 Corrosion Causing Algae

Corrosion occurred due to prolific growth of Oscillatoria algae in open steel tanks in the softening plant of the California Water and Telephone Co. (11), pitting was worst near the top of the tanks and did not occur at the bottom where lack of sunlight prevented growth of algae.

2.4 Toxic Algae

According to Gorham (12) Gonyaulax Catenella, a species of alga belonging to dinoflagellate was responsible for shell fish poisoning on the Pacific coast of North America in 1937. Prymnesium parvum is a flagellate, belonging to the yellow-brown class of algae, that can live in fresh, brackish or marine waters. It causes periodic outbreaks of fish mortality in lakes and ponds.

2.5 Control of Algae

Control of algae is generally divided into three categories, chemical, biological and physical control.

2.5.1 Chemical Control

Different chemicals are being tried to control algae. Mackenthun (13) observed that an ideal algicide for adequate control must kill the specific nuisance alga or algae. It should be non-toxic to fish and to most of the other organisms which serve as fish food at algae killing concentration. Also it should not harm seriously the ecology of aquatic area and

"be reasonable in cost". Since more than half a century the chemical which has mostly met above specifications for algae control has been copper sulfate.

Monie (14) has pointed out three important factors for control of algae with copper sulfate. These are:

i) The ability to determine when it is necessary to treat a water supply

ii) The ability to determine dose of copper sulfate to be applied for treatment

iii) Treatment should be done in such a way that copper sulfate is uniformly distributed.

There is no fixed dosage of copper sulfa t e suitable for any one condition. According to Whipple (15) seven factors are there on which the amount of copper sulfate to be applied for treatment depends:

i) The kind of algae to be destroyed
ii) The amount of organic matter present
iii) The hardness of the water
iv) The carbonic acid content
v) The temperature of water
vi) The species of fish present
vii) The amount of water to be treated

Chase (16) reported that the doses of copper sulfate of 13½ lbs. per million gallon had to be given when the count of Anabaena increased. Normal dose of copper sulfate was 2 lbs. per million gallon.

The effect of copper sulfate varies with various organisms. Copper sulfate owes its high degree of toxicity to the lower plants due to the copper ion. The toxicity of the copper ion is highest for the simplest algae, the cynophyceae (blue green) and lower for the more highly developed forms of the chlorophyceae (green algae). Protozoa are less susceptible. Diatoms are easily killed (17).

Bauer (18) observed that copper sulfate considerably reduced the threshold odors and turbidity and it is assumed that treatment of copper sulfate with 3 - 4 days reaction and settling time will kill sufficient quantities and types of algae to bring the quality of raw water to levels treatable and controlable within the plant.

In Richmand water treatment plant (19) copper sulfate is added twice, firstly before treatment and secondly after treatment to avoid algae in the distribution system.

Potassium permanganate has been used both in taste and odor control and iron and mangnese removal atleast three other uses are reported, manganese oxide hydrate acts as a coagulant aid, and potassium permanganate acts as a both bactericide and algicide (20).

In DuByne's (21) water treatment plant potassium permanganate has been found to be very effective against off flavors that are caused by algae.

Welch (22) reported that potassium permanganate eliminates tastes and odors by means of oxidation and adsorption, but this statement requires some clarification. Although potassium permanganate is an extremely strong oxidizing agent, the permanganate itself is not an adsorbing agent. It is the complex insoluble manganese oxide hydrates, formed during the oxidation process, that acts as adsorbent. In water treatment plants where potassium permanganate is being used in pretreatment, it is possible to carry a free chlorine residual of 1 ppm or more and no chlorine odor will be detectable.

Cleasby et al (23) observed that the bacterial kill due to potassium permanganate did not obey Chik's law (death rate is proportional to the number of organisms remaining). Due to strong affinity of potassium permanganate for organic matter a constant disinfection rate would not be encountered in any natural water.

Cherry (24) reported that to reduce a 200 odor to 7, 7 mg/l of permanganate (equivalent to 13.5 mg/l of carbon on cost basis) was required, carbon was not added. 30 mg/l of carbon dosage is required to reduce 200 odor to 40 with same treatment. When the odor of the raw water dropped to 40, 1 mg/l of potassium permanganate reduced the threshold odor of water

to 5, before filtration; 35 ml/l of carbon reduced the odor only to 10. These results show that potassium permanganate is very effective in reducing odors compared to activated carbon. Kemp et al (25) found that growth of nearly half of the blue green algae was inhibited by the 4 ppm concentration of potassium permanganate and that most of the algae was controlled by the 8 ppm concentration. The algicidal activity of potassium permanganate probably results from its strong oxidizing action. The rate of this reaction is greatly affected by the amount and kind of organic material living and dead, present in water.

Palin (26) reported that with 5 ppm of chlorine and 6 gpg (Imp) of alum all Euglena could be removed, while with 6 gpg alum only, removal of Euglena was less than 50%. Alum and chlorine were added together.

For controlling algae in a swimming pool, chlorine treatment in large amounts gave satisfactory results (27). Dechlorination was essential to bring down chlorine content to proper concentration.

According to Mangun (28) when chlorine was applied to the reservoir water, containing synedra, the suddenness of their disappearance was almost magical. At no subsequent time have any organisms appeared which have failed to yield to the treatment and no after effects have been observed.

Cohen (29) reported that chlorine dosage at the rate of about one part per million was applied to the water sources, namely spring and a well reservoir. As long as application of chlorine was continued, it consistently succeeded in preventing a recurrence of the heavy algae growth. However, complete freedom from algae forms was not attained, probably due to constant reseeding from the spring supply. Cohen has given advantages of using chlorine for algae control, which are as follows:

(1) Since chlorine can be employed as combined bactericide and algicide, the expense of installation and operation of additional chlorine units is not excessive.

(2) The chlorine which necessarily maintained to insure sterilization becomes effective toward inhibiting algae growth.

(3) The simplicity and economy of chlorine application and the minimum of labour and experience involved recommend its use.

(4) Since chlorine does not remain in the treated water no danger exists in cases of overdosing.

Fitzegerald (30) reported that 2 - 3 dichloro napthoquinone is lethal to blue green algae at a concentration of 2 g/l. This compound known to be an effective fungicide, seems

to be selectively toxic to the bloom producing blue green algae and higher quatic plants. In short term tests it had no toxic effect on fish and other aquatic organisms even when a dose of 100 g/l of 2 - 3 dichloro napthoquinone was given.

Spray applications (31) of 2 - 3 dichloro napthquinone (2 - 3 CNQ) suspensions to give overall concentrations from 30 to 55 ppp in the lake, clumped and effectively killed even heavy growths of blue green species. The chemical treatment had no observable harmful effects on green algae, higher aquatic plants, fish or zooplankton. In cases of rapid recurrence of growth of the blue green algae, repeated applications are necessary. The lasting effect of treatment, however, may be indirectly increased by vigorous growth of green algae and higher aquatics following the suppression of blue green.

Laboratory and field studies show that 3 - (p-chlorophenyl)-1, 1 dimethyl urea (CMU) is an effective algicidal agent (32). It was found in the laboratory tests that 2 ppm of CMU prevented all the species of blue green algae and diatoms tested. While applying CMU care is to be taken. It is a selective herbicide at certain concentrations, but it is soil sterilant at higher concentrations.

2.5.2 Biological Control of Algae

When feasible nuisance growths of algae can be limited or prevented by limiting the area of shallow water in reservoirs by maintaining high water levels and by limiting nutrients from

soil erosion, sewage and treatment plant effluents and other sources (9).

Algae was controlled in a pond by stocking fish (32). Microscopic organisms form the basis of the food supply of fish and other aquatic animals. This relationship is summed as no plankton no fish. Fish when feeding, swims with its mouth open. The water enters the mouth and passes out through the gills, which acts as a filtering apparatus by which the minute organisms are caught.

Safferman (33) reported that the destructive power of the blue green algae (BGA) virus could serve as a highly potent and selective algae control, thus making it possible to eliminate the use of the potentially dangerous chemicals that are presently employed in the treatment of algae problems. Because of the highly selective nature of viruses, it seems unlikely that the virus would infect other plants or animals. Consequently, no toxicity problems should be encountered upon treatment of water supplies with such agents.

2.5.3 Physical Control of Algae

Microstraining is a form of simple filtration. The object of microstraining is the clarification of liquids by filtering out a large portion of the suspended matter present in water supplies or, in some applications, sewage effluents. Chlorophyceae (green algae) and cyanophyceae (blue green algae) have given

trouble in the past. No difficulty is anticipated in removing them from the water by microstraining. The microstraining unit is mounted in and on a rectangular steel tank. The steel tank is divided into a small raw-water chamber located at one end, and a chamber of strained water. In the strained-water chamber a rotating drum unit is located. The drum is driven by an electric motor directly connected to a variable speed reduction gear. Speeds of the drum can be varied from 0.5 to 4.0 rpm. The periphery of the drum is covered with a fine stainless steel cloth. This microstraining fabric has 160,000 openings per square inch, with size as small as 23 . The water to be strained enters the drum axially and flows radially through the fabric (34).

According to Berry (35) the microstrainers are effective in the removal of algae. The cost of treatment is normally low. They can be used either as the sole treatment for community and industrial water supplies, or they can be a valuable primary treatment ahead of filtration.

Tastes and odors were eliminated from the pond of 108 acres that furnishes the supply of Pembroke and two other Massachusetts towns by use of activated carbon without subsequent filtration (36). Copper sulfate applied at 3 ppm was ineffective, so copper sulfate followed by activated carbon was tried, both applied from motors, copper sulfate at the rate of .6 ppm, and carbon at 1.25 ppm. The next day no taste, odor, turbidity or carbon was found in the tap water.

Activated carbon was applied by dryfeed equipment to the suction line of raw water pumps at the Brandywine pumping station at a rate of 2 ppm (37). The carbon was thoroughly mixed during its passage through 2 miles of 48 inches main before the water entered the reservoir. The 2 ppm rate appeared to allow a penetration of sunlight about 1.5 to 2 ft. The reduction in algae count due to the blackout resulted in lower dosages of alum, chlorine and copper sulfate. Washwater use was reduced and overall improvement of taste and odor conditions was experienced.

The materials used and the methods employed for the study are described in the following chapter.

3. MATERIALS AND METHODS

3.1 Types of Algae Used in Experiments

In the present study, in all, three dominating algae were used, Chlorella, Ulothrix and Arthrospira. The description of each alga, used in experiments, is given below.

3.1.1 Chlorella

Chlorella comes under green algae. It is single celled. Chlorella contains a single U-shaped chloroplast that lies adjacent to the cell wall. If the cell under observation is oriented correctly, the shape of the chloroplast and its location within the cell may be distinctly seen. It has been employed extensively in studies on photosynthesis and respiration. It may well be that from Chlorella we shall learn the secret of combining water and carbon dioxide to form sugar (38). Sketch of Chlorella is shown in Fig. 2.

3.1.2 Ulothrix

Ulothrix belongs to the group of green algae. It is a common thread like alga, its short cells each containing a single nucleus and a large, gridle-shaped chloroplast. It forms a hairy covering on rocks in cool streams and similar situations, but it can live equally when unattached. Each filament is attached to the rock or other solid object by a basal cellor hold fast, which is narrow, elongate, and generally lacking in Chlorophyll (39)

3.1.3 Arthrospira

Arthrospira comes under blue green algae. It is closely related to Oscillatoria, but is different from it in that Arthrospira plants are bent to the form of a regular spiral. Arthrospira may be found occasionally in stagnant or brackish water (40).

3.2 Sources of Algae, Used in Experiments

The three different types of algae were obtained from three different sources. Short description of these sources is as follows:

3.2.1 Source of Chlorella

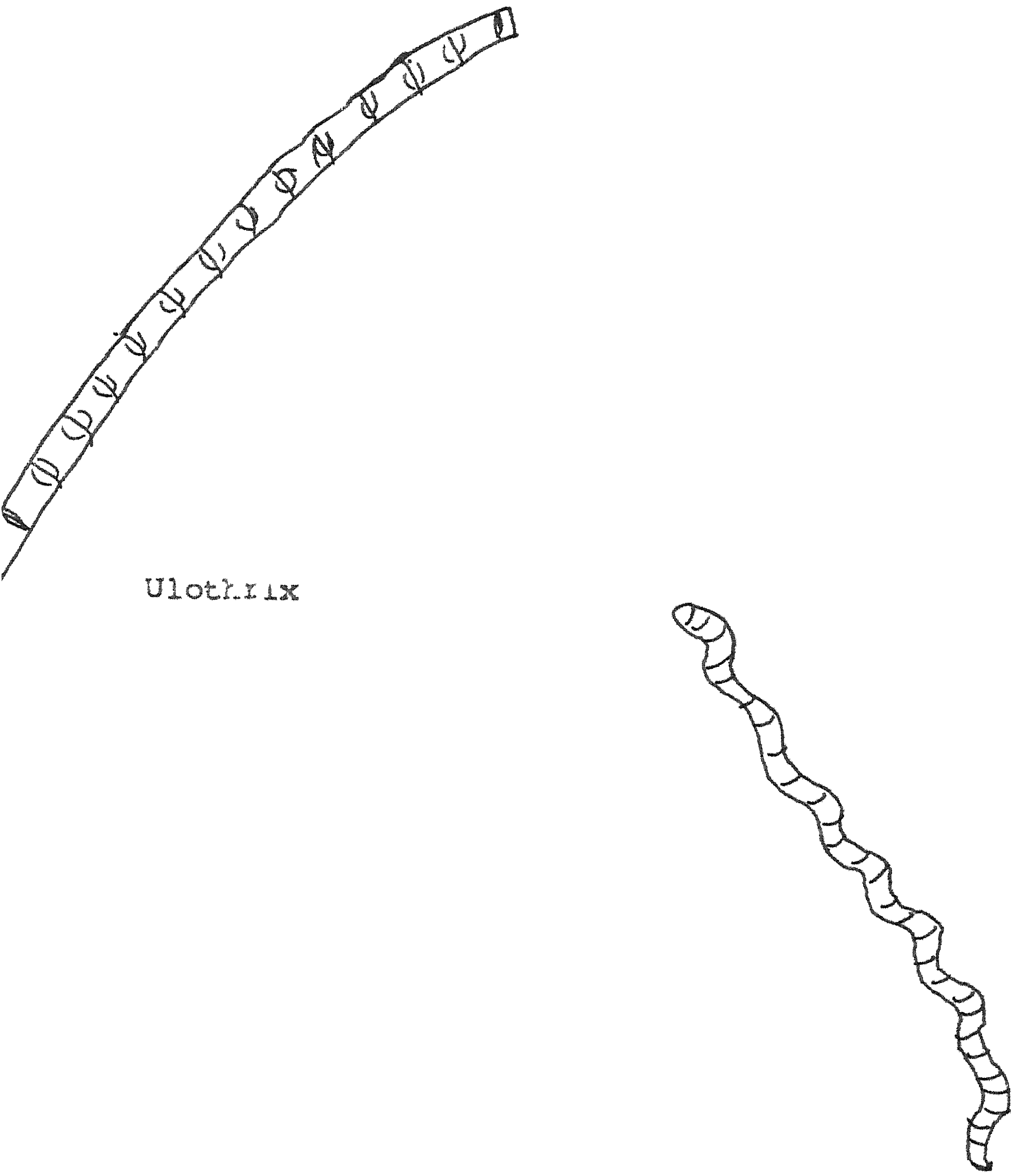
The samples in which Chlorella were dominating, were obtained from the laboratory oxidation pond. This pond was being used for the treatment of the fertilizer factory wastes. The light was provided by means of tube lights. When the pond started working Chlorella were dominating, and they remained dominating till end.

3.2.2 Source of Ulothrix

Ulothrix were obtained from a small canal, in the nursery, which is used for watering the plants. Lot of Ulothrix were thriving on that water. The water contained fertilizer also since fertilizer was fed to plants after dissolving in water.

3.2.3 Source of Arthrospira

Arthrospira dominating samples were obtained from the campus oxidation pond. The campus oxidation pond is used for



[illegible] 3

Algae used in the [illegible]

thre treatment of the domestic waste of the campus.

3.3 Chemicals used in the Study

The chemicals used in the experiments could be divided into two categories, (i) chemicals used for flocculation, and (ii) chemicals used to see their effect on algae removal. Chemicals used for flocculation were ferric chloride and alum. The chemicals, used to see their effect on algae removal, were copper sulfate, potassium permanganate, Chlorine, lime, iodine and animal charcoal. A brief description of how these chemicals were employed in present study is given.

A solution of ferric chloride was prepared in a distilled water by dissolving 5 g. of ferric chloride in 500 ml. water. Hence 1 ml. of this solution was equivalent to 10 mg. of ferric chloride. Two to three drops of strong hydro chloric acid were added to this to avoid precipitation.

10 gms. of aluminium potassium sulfate was dissolved in distilled water, so that 1 ml. of this solution contained 10 mg. of alum.

0.5 gm. of copper sulfate was dissolved in distilled water. Few drops of strong sulfuric acid were added to this solution because in alkaline waters precipitation of copper carbonate takes place.

A solution of potassium permanganate was prepared by dissolving 0.5 gm. of potassium permanganate in 500 ml. distilled

water. One ml. of this solution contained 1 mg. of potassium permanganate. The solution was kept in dark to avoid the reaction with light.

The strength of chlorodak was found according to standard methods (41) and then such amount of chlorodak was added to 500 ml. distilled water so that chlorine concentration was 1 mg./ml. The solution thus prepared was kept in a tight bottle so that chlorine may not escape.

Calcium oxide was used to see whether it aids removal of algae. The required amounts were weighed on analytical balance and dry feeding was done.

The iodine solution of 100 mg./l. was prepared by dissolving iodine with potassium iodide in water. One ml. of this solution contained 1 mg. of iodine.

To see the effect of animal charcoal on algae removal, it was fed dry to samples containing algae, after weighing required amounts on analytical balance.

3.4 Methods

A preliminary experiment was conducted to find the optimum wave length for Chlorella to find absorbance. The wave length was found to be 440 m . The optimum wave length for Arthrospira dominating samples was also found to be same.

Calibration curve was prepared between algae concentration in mg./l. versus absorbance. The filter papers, Whatman No. 42,

were dried in an oven, and weighed after cooling in dessicator.

Different concentrations of algae (Chlorella dominating) were prepared by dilutions, their absorbance were noted down. Weight of algae in respective samples was found by filtering 500 ml. volume of algae through Whatman No. 42, after drying in oven at 110°C for 30 minutes and then cooling in dessicator. Calibration curve is shown in Fig. 4.

The concentrations of algae in all the experiments, except one that was conducted on Ulothrix, were found spectrophotometrically. For flocculation stirrer was used. Measurement of pH was done with pH meter.

Since disinfection is attained by heating the water (42) one experiment was conducted to see the effect of heat treatment on algae removal.

The details of the experiments conducted and the results obtained are given in the following chapter.

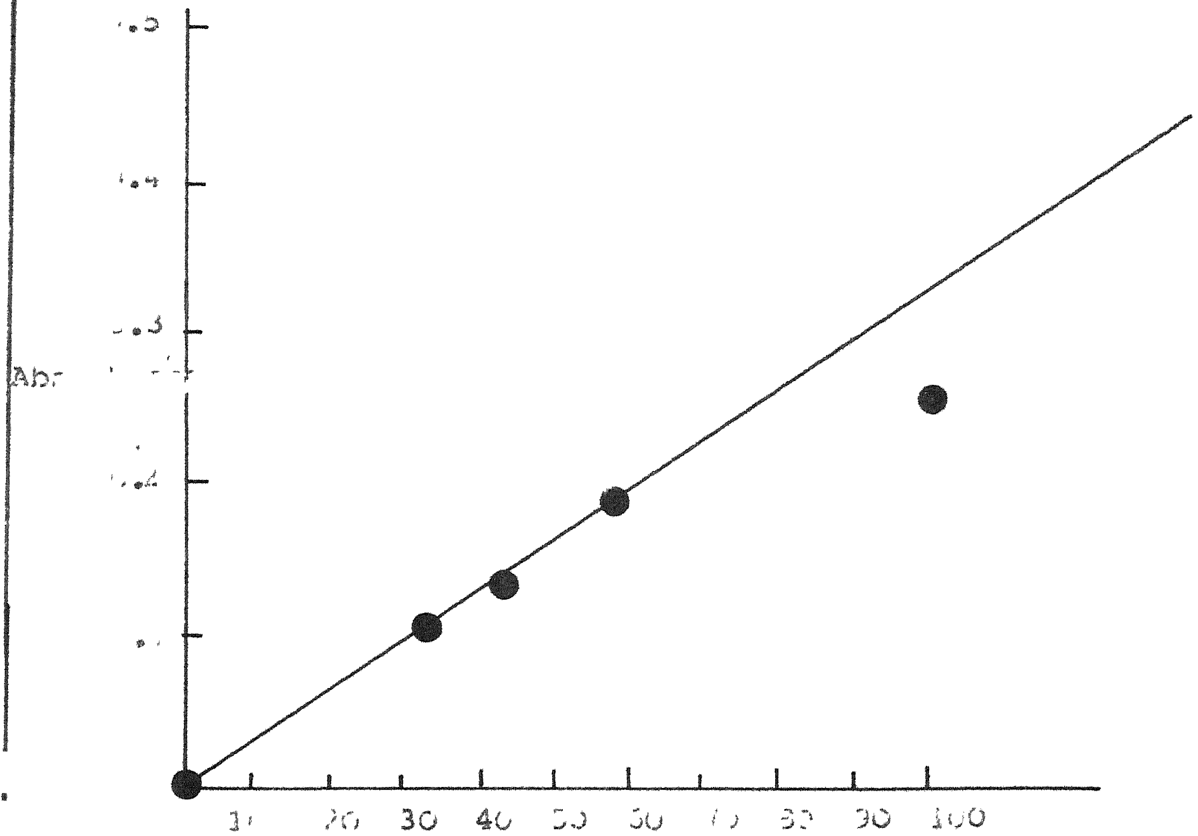


Fig 4. Calibration Curve for Algae concentration

4. EXPERIMENTS AND RESULTS

Experiments were conducted with three different waters containing three different algae. In one water Chlorella, the green algae, were dominating and second Arthrospira, the blue green algae, were dominating and in third Ulothrix, green algae were dominating.

The volume of samples taken for all the experiments was 500 ml. In all the experiments wherever flocculation and sedimentation were employed, the flocculation was done at 60 rpm for 15 minutes and the settling time given was 30 minutes (43).

4.1 Removal of Algae with Different Chemicals by Plain Sedimentation

In this experiment to Chlorella dominating samples concentrations of 1, 5 and 10 mg/l of different algicides namely, copper sulfate, potassium permanganate, chlorine were added. The chemicals were completely mixed by stirring and the allowed to stand. The beakers were exposed to sunlight. The algae removal was found after every 24 hours up to 3 days. The results are shown in Fig. 5 to 7.

4.2 Effect of Algicides on Removal of Algae by Plain Sedimentation

In this experiment the effect of copper sulfate and potassium permanganate by plain sedimentation is seen. To the Chlorella containing samples, the doses of copper sulfate and potassium permanganate varying from 0 to 18 mg/l were applied.

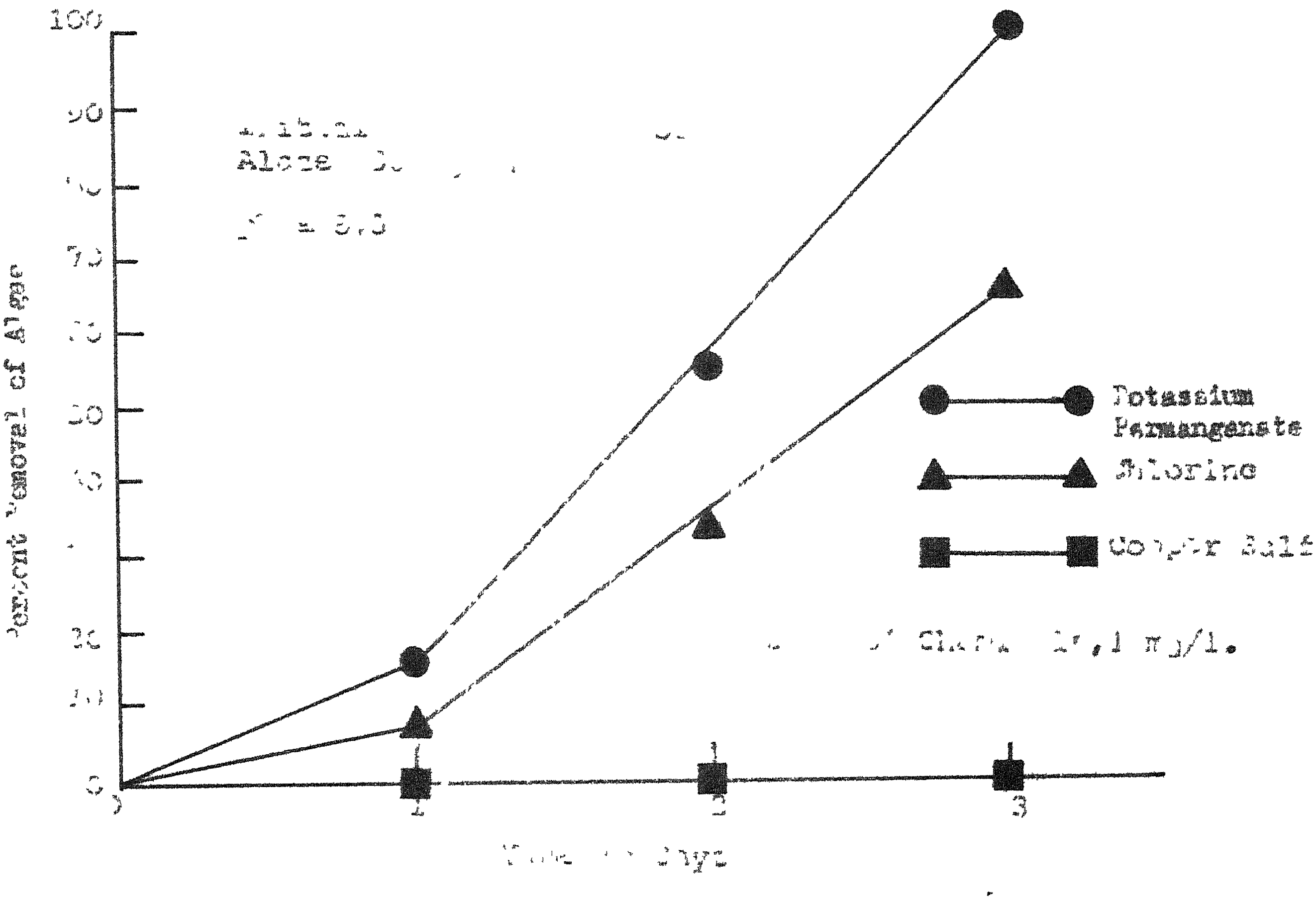


Fig 5. Removal of Algae with different chemicals

by [illegible] Sedimentation.

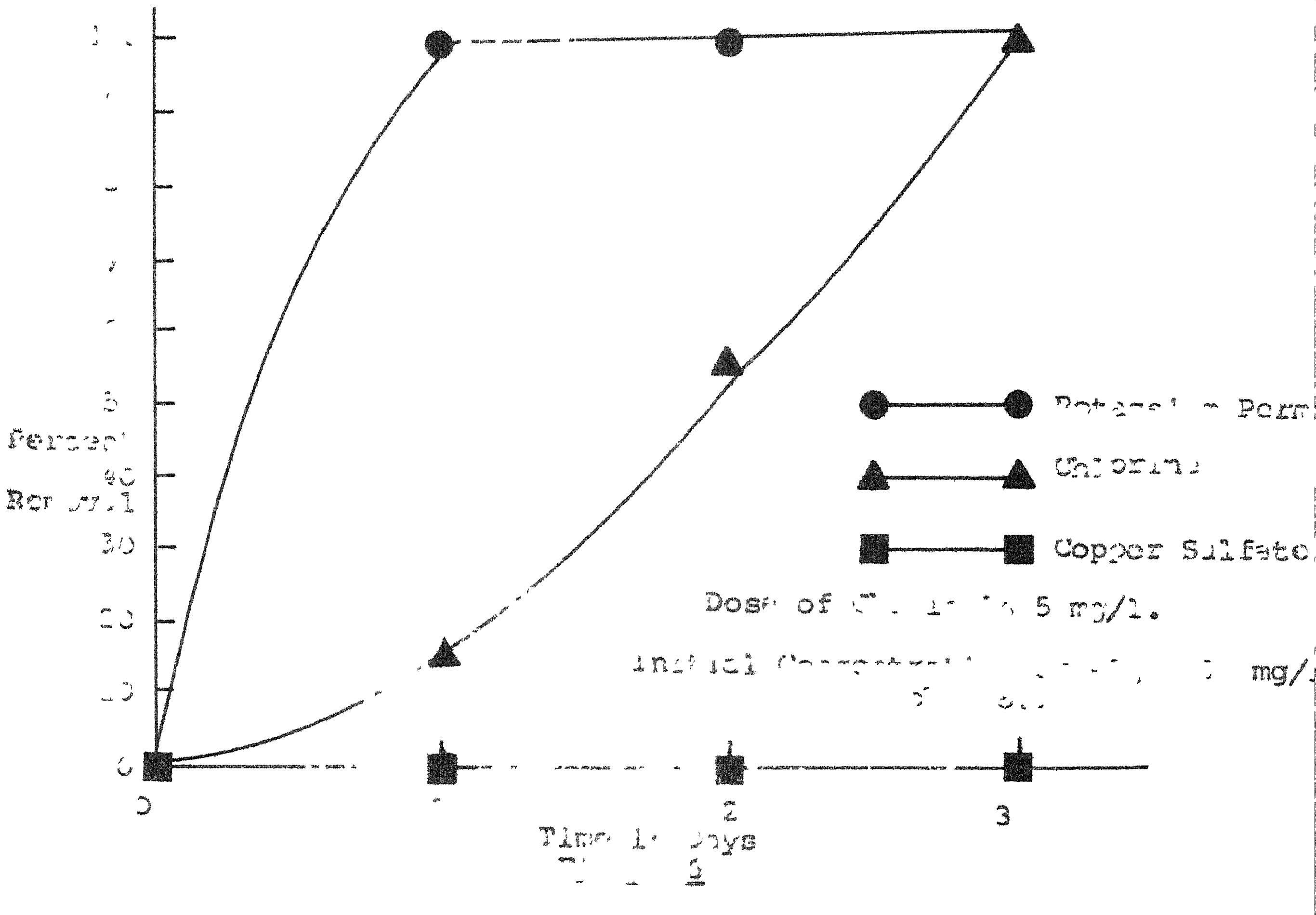


Fig 6. [illegible] of algae with different chemicals
by plain [illegible]

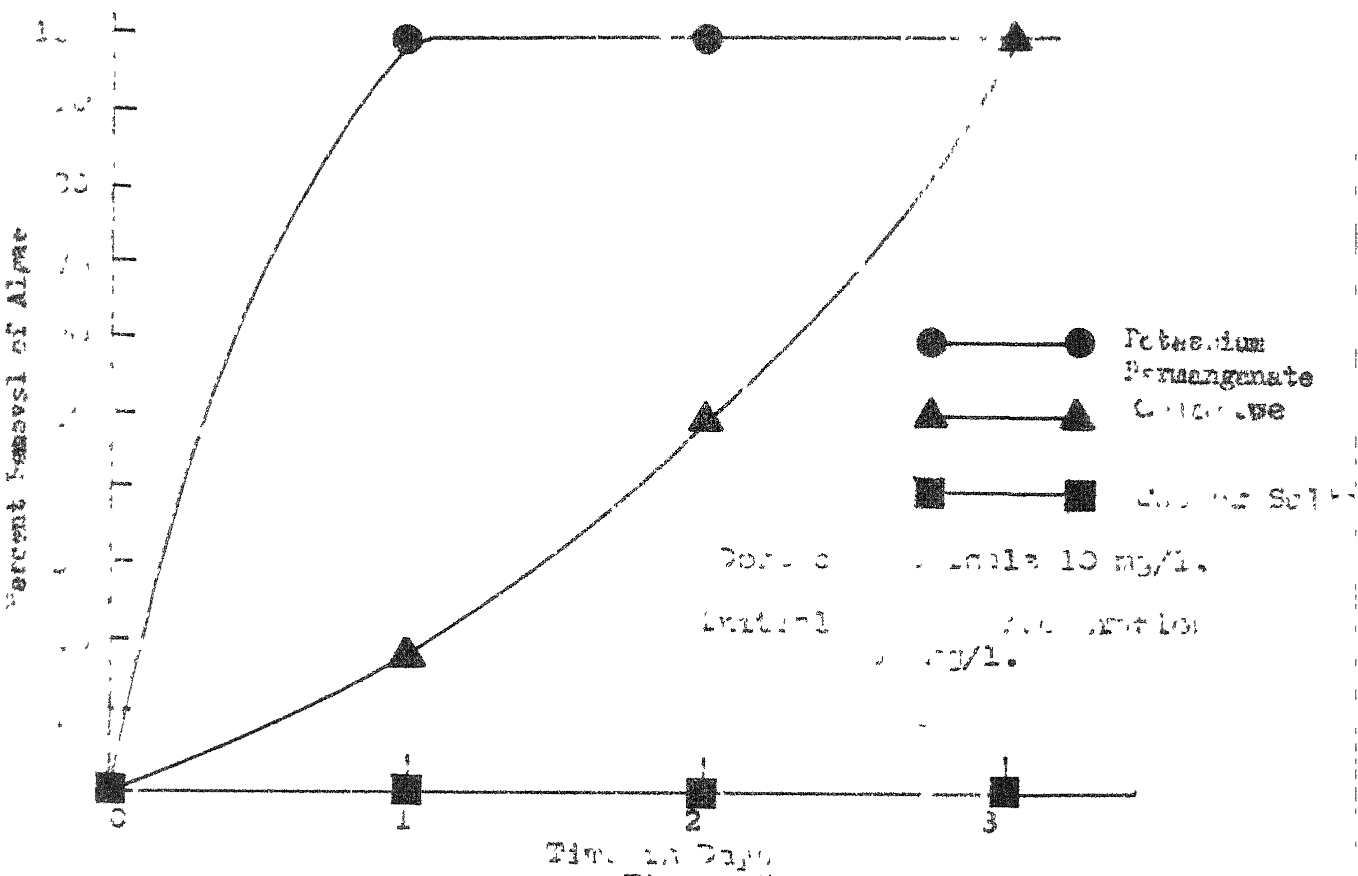


Figure 7

Fig 7. Removal of Algae ... by plain sedimentation.

After mixing the samples were allowed to stand for 24 hours. Percent removal of algae was determined after finding the concentrations of algae remaining in supernatant. The results are reported in Fig. 8.

4.3 Effect of Algicides on Removal of Algae when Flocculation and Sedimentation is done

To samples containing Chlorella different doses of copper sulfate were added. The doses used were 0 mg/l, 1 mg/l, 2 mg/l, 3 mg/l, 4 mg/l and 5 mg/l. The contact time of 1 hour was given for copper sulfate to react with Chlorella. After that 200 mg/l alum was added as coagulant to all the samples. All the samples were flocculated and allowed to settle. In the supernatant the concentration of remaining algae was estimated from which the percent removal of algae was found. The results are reported in Fig. 9.

Similar experiment was carried out, with potassium permanganate. The doses of potassium permanganate used were similar to those of copper sulfate. Fig. 9 shows results.

4.4 Effect of Contact Time given for Potassium Permanganate on Removal of Algae

This experiment was conducted to see the effect of contact time provided for potassium permanganate to react, on algae removal. Samples containing Chlorella were given a dose of 2 mg/l of potassium permanganate. After allowing different contact times, varying from 0 to 4 hours, flocculation was done with 100 mg/l of alum followed by sedimentation. The algae

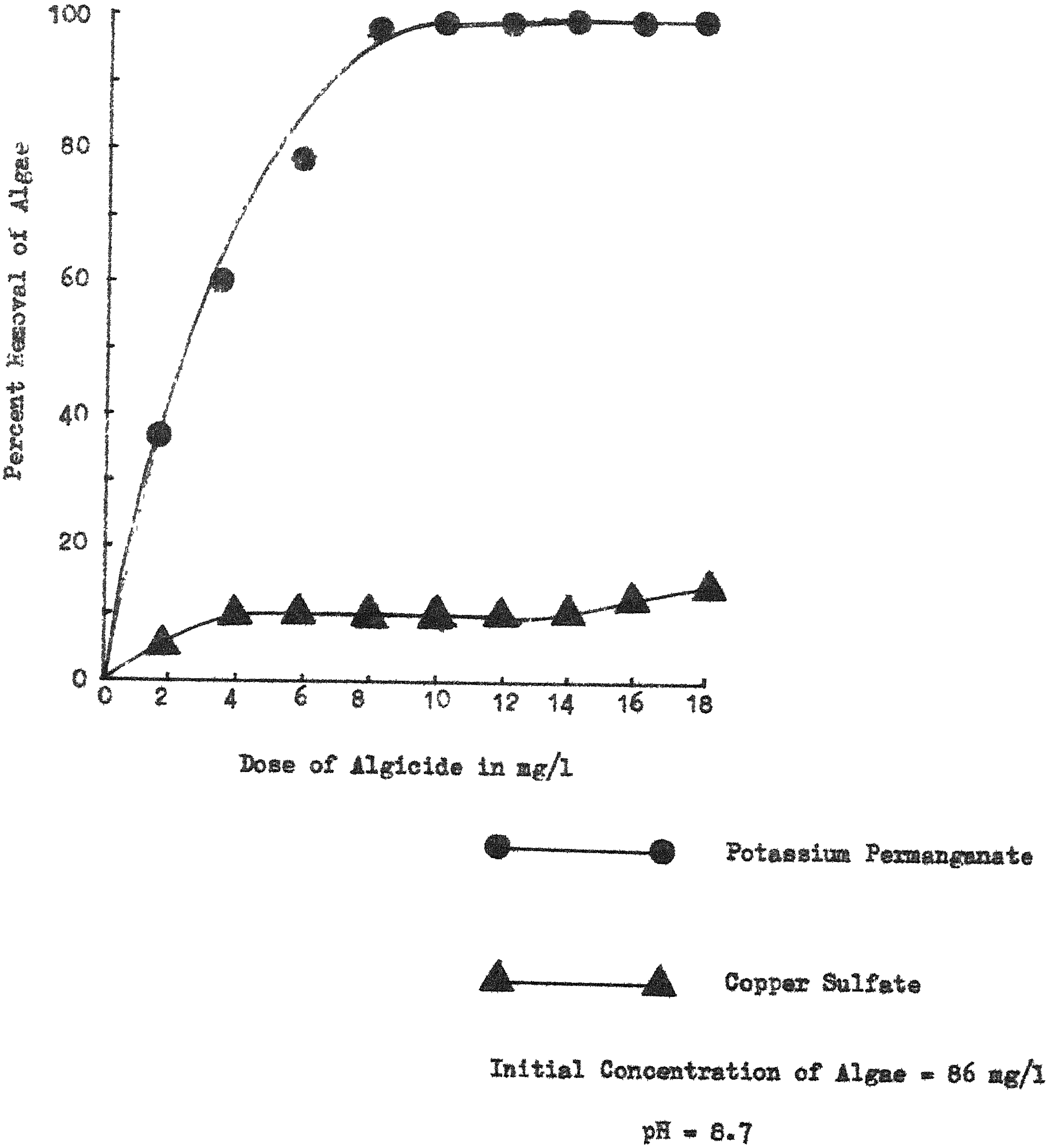


Fig 8. Effect of Algicides on Removal of Algae
by plain Sedimentation

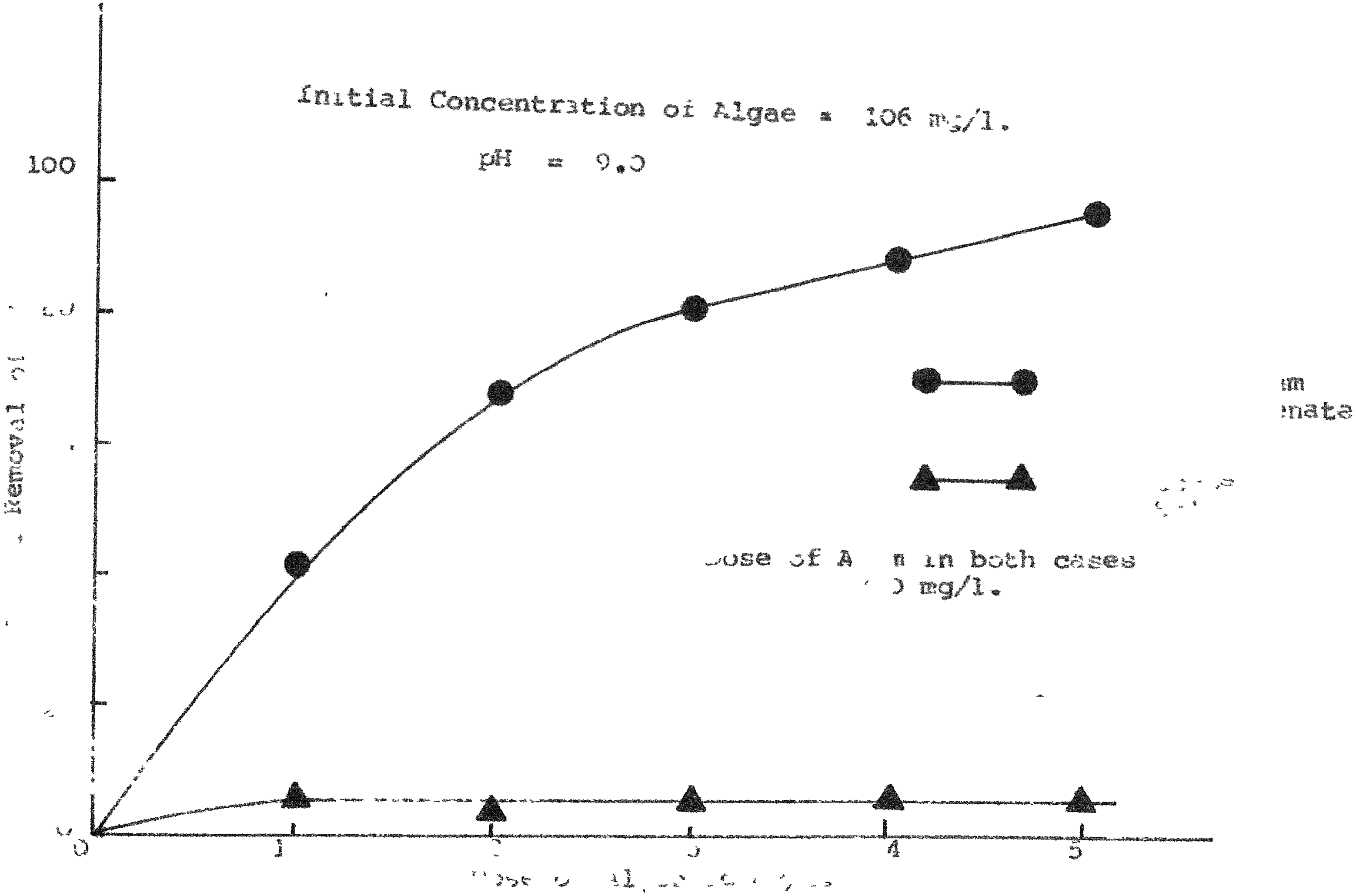


Figure 9

Fig 9. Effect of Algicides on removal of Algae when Flocculation and Sedimentation is done

concentration remaining in the supernatant was determined with spectrophotometer. The results are shown in Fig. 10.

Similar experiment was conducted to find the effect of contact time on algae removal with 1 mg/l and 0.5 mg/l of potassium permanganate. The results are reported in Fig. 11.

4.5 Effect of Potassium Permanganate on the Optimum Dose of Alum

In this experiment the optimum dose of alum with and without addition of potassium permanganate was determined. The doses of alum varying from 0 to 1800 mg/l were applied, flocculation and sedimentation was done and the percent removal of algae was found by determining concentration of algae remaining in the supernatant. Then similar experiment was conducted but in this case 2 mg/l of potassium permanganate was added to all the samples and a contact time of 2 hours was allowed. The flocculation was done by different dosages of alum and then sedimentation. The results are plotted in Fig. 12.

4.6 Effect of Potassium Permanganate on the Optimum Dose of Ferric Chloride

In this experiment the optimum dose of ferric chloride with and without potassium permanganate was determined. To samples containing Chlorella the doses of ferric chloride varying from 0 to 800 mg/l were applied, flocculation and sedimentation.was done. The concentration of algae remaining in the supernatant was found, to determine percent removal of algae. Results are shown in Fig. 13. In similar experiment 2 mg/l of

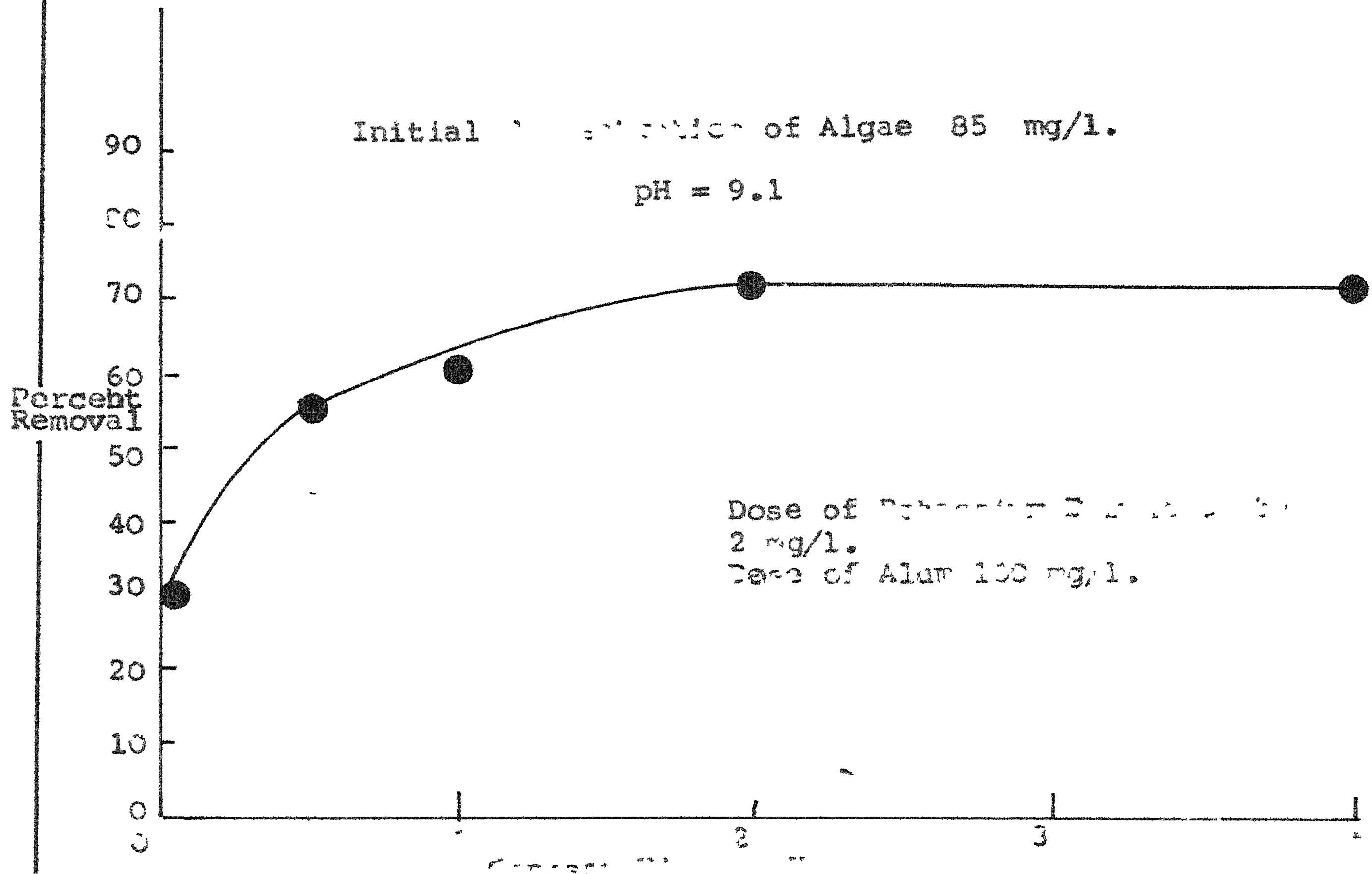


Figure 10 (Same title as Fig 11.)

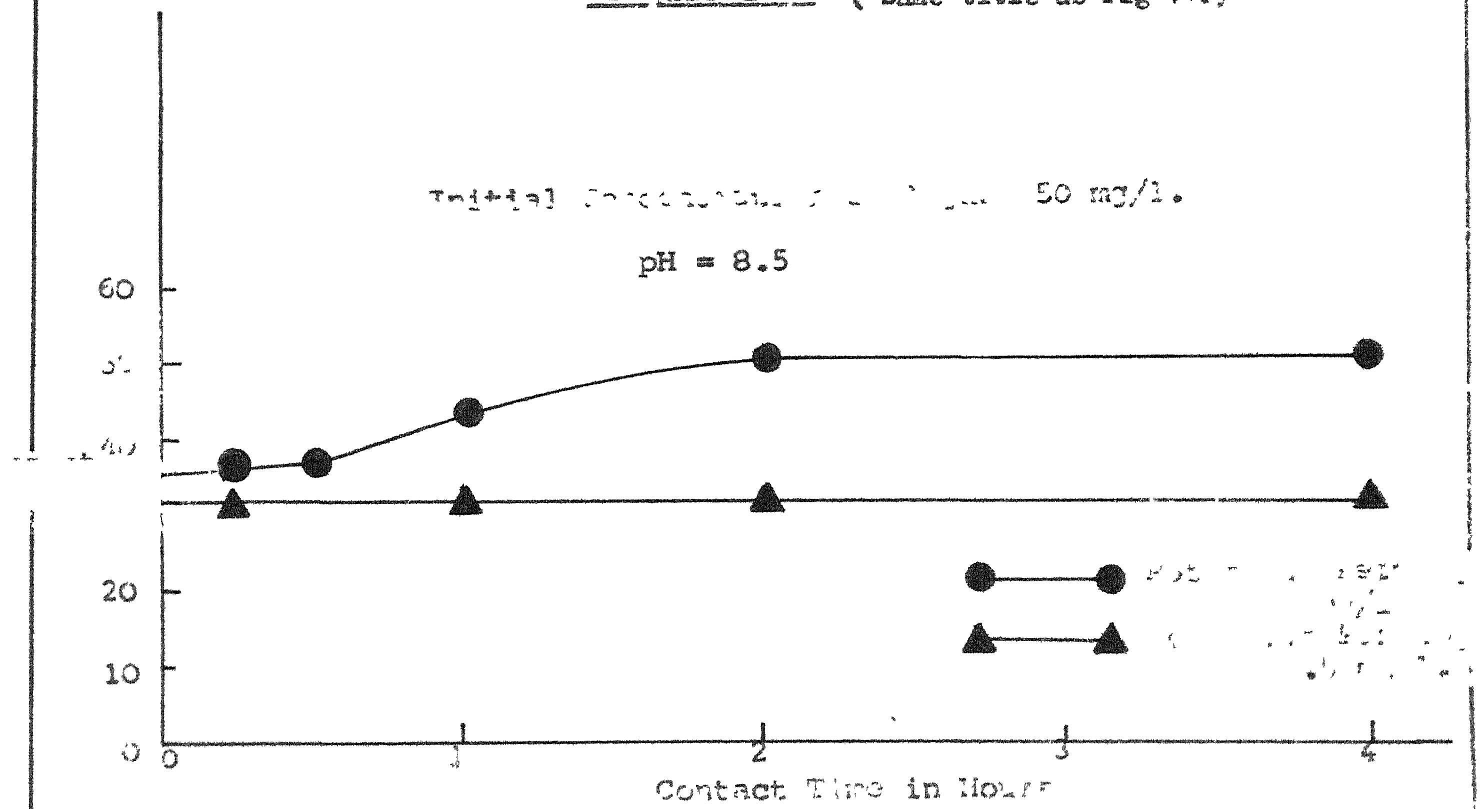


Figure 11

Fig 11. Effect of Contact Time given for Potassium

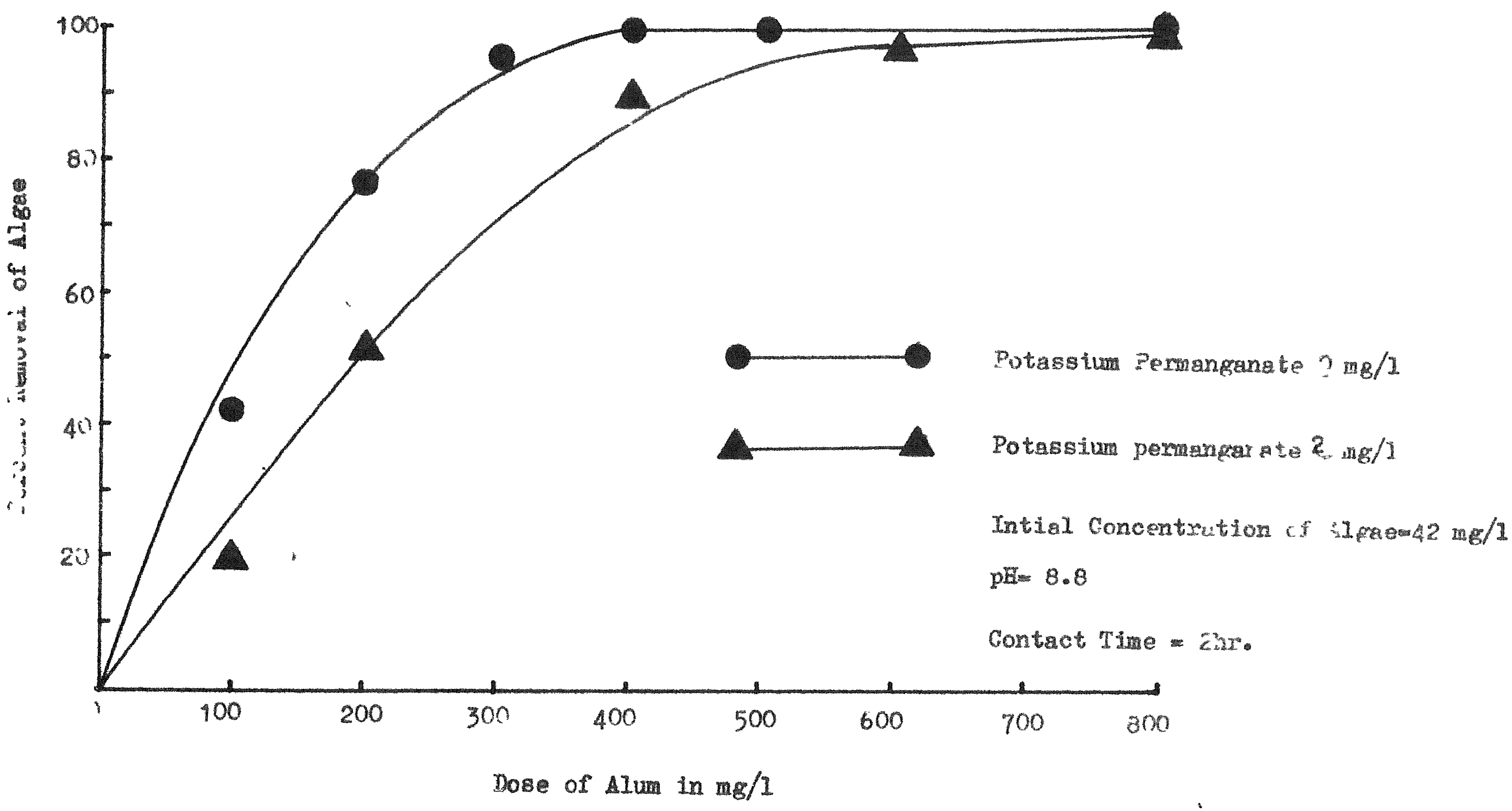


Fig 12. Effect of Potassium Permanganate on the Optimum dose of Alum

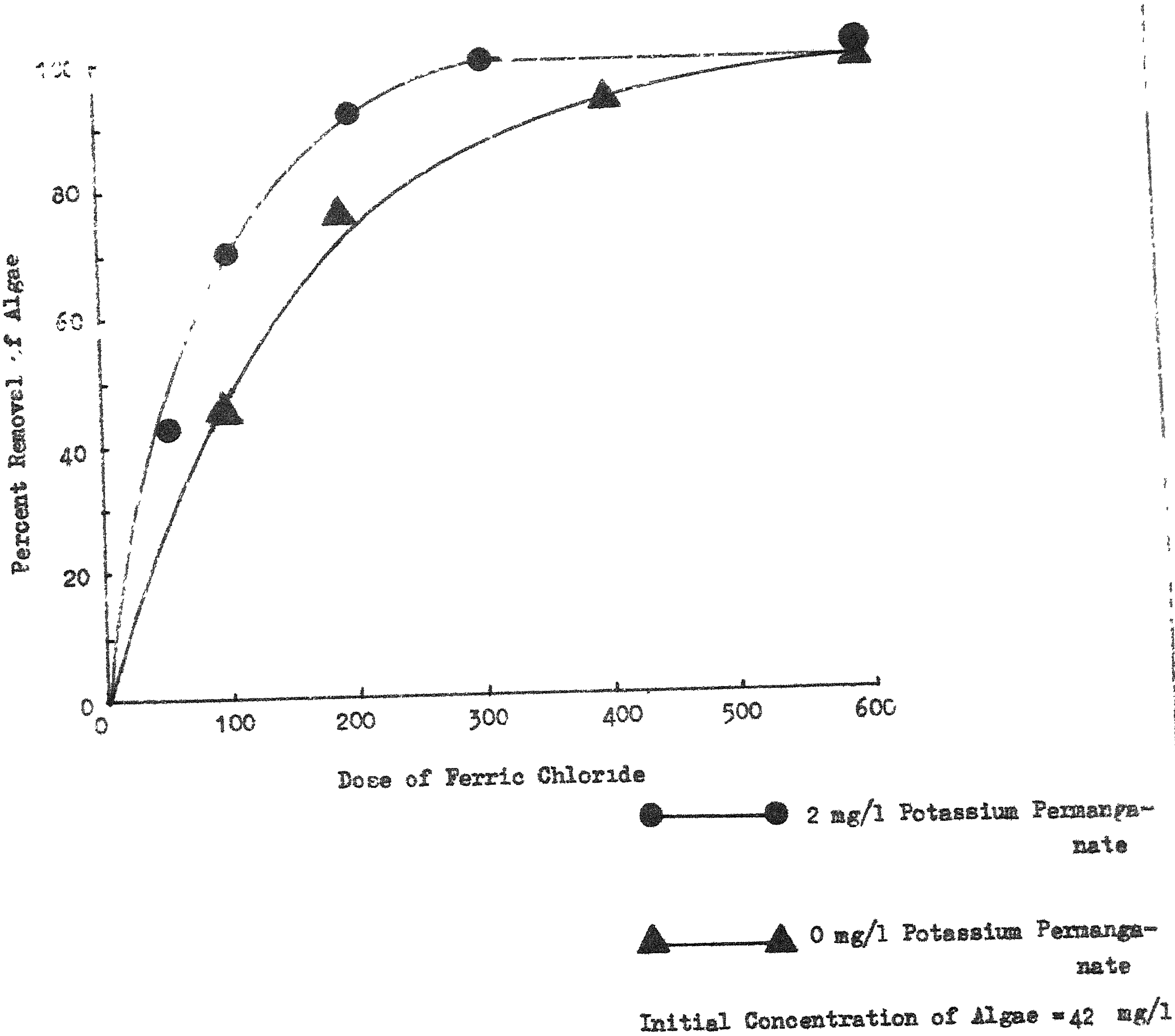


Fig 13. Effect of Potassium Permanganate on the Optimum dose of Ferric Chloride.

potassium permanganate was applied to samples containing Chlorella, 2 hours contact time was provided and then the different doses of ferric chloride were given. Flocculation was done and then sedimentation followed. To estimate percent removal of algae the concentration of algae remaining in the supernatant was found. The Fig. 13 shows the results.

4.7 Effect of Chlorine on Algae Removal

This experiment was conducted to see whether the removal of algae is enhanced by the addition of chlorine prior to flocculation. The doses of chlorine varying from 0 to 60 mg/l were added to Chlorella dominating samples. 1½ hour contact time was given and then flocculation was done with 100 mg/l of alum. Sedimentation was done after flocculation. In the supernatant, concentration of algae was determined to find the percent removal of algae. The results are tabulated in Table 1. Similar experiment was conducted but in this case the doses of chlorine applied, varied from 0 to 150 mg/l. The results are tabulated in Table 2.

4.8 Determination of Optimum Contact for Chlorine for Removal of Algae

These experiments were carried out to find the optimum contact time for chlorine. The dose of 20 mg/l of chlorine was applied to the samples containing Chlorella. After providing a contact time, which varied from 0 to 4 hours, flocculation was done with 100 mg/l of alum sedimentation followed it. Percent removal of algae was found by determining the concentration

TABLE 1.

Effect of Chlorine on Algae Removal

Initial Concentration of Algae 80 mg/l.

pH = 8.5

Contact Time = 1½ hour

Jar No.	Dose of Chlorine	Dose of Alum	Absorbance	% Removal of Algae
Control	0 mg/l	0 mg/l	0.27	-
1	0 mg/l	100 mg/l	0.22	0
2	10 mg/l	100 mg/l	0.21	4.55
3	20 mg/l	100 mg/l	0.19	13.65
4	30 mg/l	100 mg/l	0.18	18.20
5	60 mg/l	100 mg/l	0.15	31.80

TABLE 2.

Effect of Chlorine on Algae Removal

Initial Concentration of Algae 82 mg/1.

pH = 8.5

Contact Time = 1½ hour

Jar No.	Dose of Chlorine	Dose of Alum	Absorbance	% Removal of Algae
Control	0 mg/l	0 mg/l	0.28	-
1	0 mg/l	100 mg/l	0.23	0%
2	50 mg/l	100 mg/l	0.16	30.4
3	80 mg/l	100 mg/l	0.15	34.8
4	100 mg/l	100 mg/l	0.145	37.0
5	150 mg/l	100 mg/l	0.135	41.3

of algae remaining in the supernatant. The resuls are tabulated in Table 3. Similar experiment was conducted but in this case dose of Cchlorine applied was 10 mg/l. In Table 4 results are tabulated.

4.9 Effect of Lime on Algae Removal

This experiment was conducted to see whether lime aids the removal of Chlorella. The doses of lime (dry) varying from 0 to 2 gm/l were applied to Chlorella dominating samples. The contact time of 2 hours was given. Flocculation was done with 50 mg/l of alum followed by sedimentation. The pH of the supernatant and the concentration of algae remaining was determined. The results are tabulated in Table 5.

4.10 Effect of Animal Charcoal on Removal of Algae

The effect of animal charcoal on algae removal is seen in this experiment. The contact time provided was 2 hours. The doses of animal charcoal varying from 0 to 8 gm/l were applied to samples containing Chlorella. 100 mg/l of alum was added for flocculation and then sedimentation was done. The results are tabulated in Table 6.

4.11 Effect of Iodine on Algae Removal

Effect of iodine on algae removal was studied in this experiment. The doses of iodine used varied from 0 to 40 mg/l. Contact time of 2 hours was provided. The samples were then flocculated with 100 mg/l of alum and then sedimentation was

TABLE 3.

Determination of Optimum Contact Time for Chlorine for Removal of Algae

Initial Concentration of Algae 51 mg/l

pH = 8.6

Dose of Alum = 100 mg/l

Jar No.	Dose of Chlorine	Contact Time	Absorbance	Percent Removal of Algae
1	0 mg/l	-	0.115	0
2	20 mg/l	¼ hr.	0.09	21.8
3	20 mg/l	½ hr.	0.085	26.1
4	20 mg/l	1 hr.	0.085	26.1
5	20 mg/l	2 hrs.	0.085	26.1
6	20 mg/l	4 hrs.	0.085	26.1

TABLE 4.

Determination of Optimum Contact Time for Chlorine for Removal of Algae

Initial Concentration of Algae 51 mg/l

pH = 8.6

Dose of Alum = 100 mg/l

Jar No.	Dose of Chlorine	Contact Time	Absorbance	% Removal of Algae
1	0 mg/l	-	0.115	0
2	10 mg/l	¼ hr.	0.100	13.05
3	10 mg/l	½ hr.	0.100	13.05
4	10 mg/l	1 hr.	0.100	13.05
5	10 mg/l	2 hrs.	0.100	13.05
6	10 mg/l	4 hrs.	0.100	13.05

TABLE 5.

Effect of Lime on Algae Removal

Initial Concentration of Algae 64 mg/l.

pH = 8.9

Contact Time = 2 hours

Dose of Alum = 50 mg/l

Jar No.	Dose of Lime	Absorbance	pH	Percent Removal of Algae
1	0.0 gm/l	0.215	8.8	0
2	0.4 gm/l	0.165	9.7	46.5
3	0.8 gm/l	0.01	10.75	95.4
4	1.2 gm/l	0.000	11.8	100.0
5	1.6 gm/l	0.000	12.15	100
6	2.0 gm/l	0.000	12.2	100

TABLE 6

Effect of Animal Charcoal on Removal of Algae

Initial Concentration of Algae 72 mg/l

pH = 9.0

Contact Time = 2 hours

Jar No.	Dose of Charcoal	Dose of Alum	Absorbance	Percent Removal of Algae
1	0 gm/l	100 mg/l	0.20	0
2	1 gm/l	100 mg/l	0.20	0
3	2 gm/l	100 mg/l	0.175	12.5
4	4 gm/l	100 mg/l	0.10	50
5	6 gm/l	100 mg/l	0.085	57.5
6	8 gm/l	100 mg/l	0.045	77.5

employed. Results of the experiment are tabulated in Table 7.

4.12 Experiment on Ulothrix with Potassium Permanganate

This experiment was carried out to see the effect of potassium permanganate on Ulothrix. The doses of potassium permanganate applied were 0, 2, 5 and 10 mg/l. After 8 days the height of algae zone from bottom was measured in each jar. The results are shown in Fig. 14.

4.13 Removal of Low Concentration of Arthrospira Dominating Algae with Copper Sulfate, Potassium Permanganate and Alum

On low concentration of Arthrospira dominating samples the experiments were conducted. The doses of potassium permanganate varying from 0 to .8 mg/l were applied to the samples. The contact time of 1 hour was given and then flocculation was done with 50 mg/l of alum followed by sedimentation. Since the samples were very dilute centrifuging was done at 5000 rpm for 15 minutes. 40 ml samples were used for centrifuging after that samples were reduced to 5 ml and then concentration of algae was found. Similar experiment was conducted by applying copper sulfate. Fig. 15 shows the results.

4.14 Effect of Algicides on Optimum Dose of Alum in Case of Arthrospira Dominating Samples

This experiment was carried out to find the effect of copper sulfate and potassium permanganate on the optimum dose of alum. First experiment was conducted without addition of either potassium permanganate or copper sulfate. Only flocculation was done at 0 to 1000 mg/l dosages of alum which was

TABLE 7

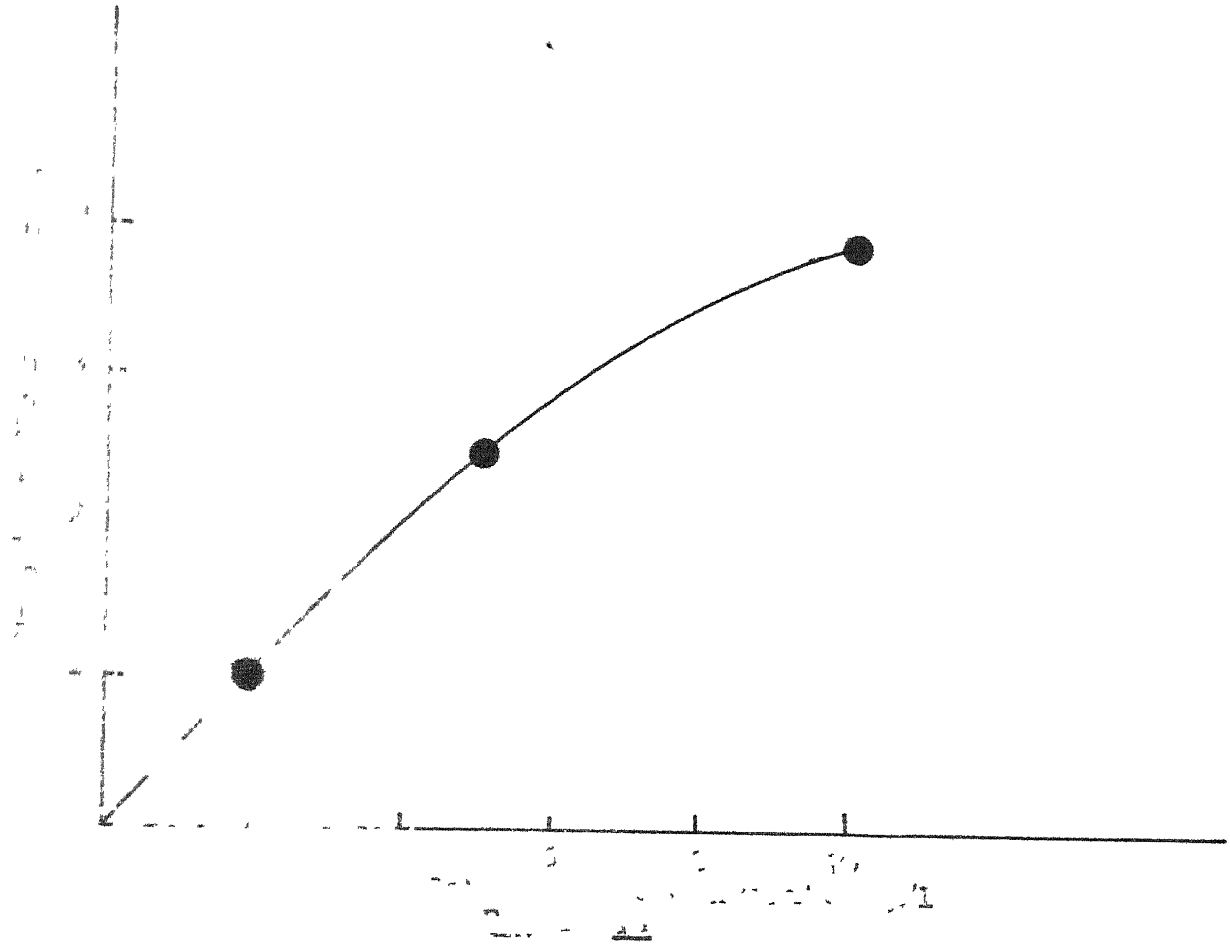
Effect of Iodine on Algae Removal

Initial Concentration of Algae 32 mg/l.

pH = 8.9

Contact Time = 2 hours

Jar No.	Dose of Iodine	Dose of Alum	Absorbance	% Removal of Algae
1	0 mg/l	100 mg/l	0.055	0
2	5 mg/l	100 mg/l	0.055	0
33	10 mg/l	100 mg/l	0.05	9.1
4	20 mg/l	100 mg/l	0.05	9.1
5	40 mg/l	100 mg/l	0.04	27.2



Potassium Permanganate on Calothrix.

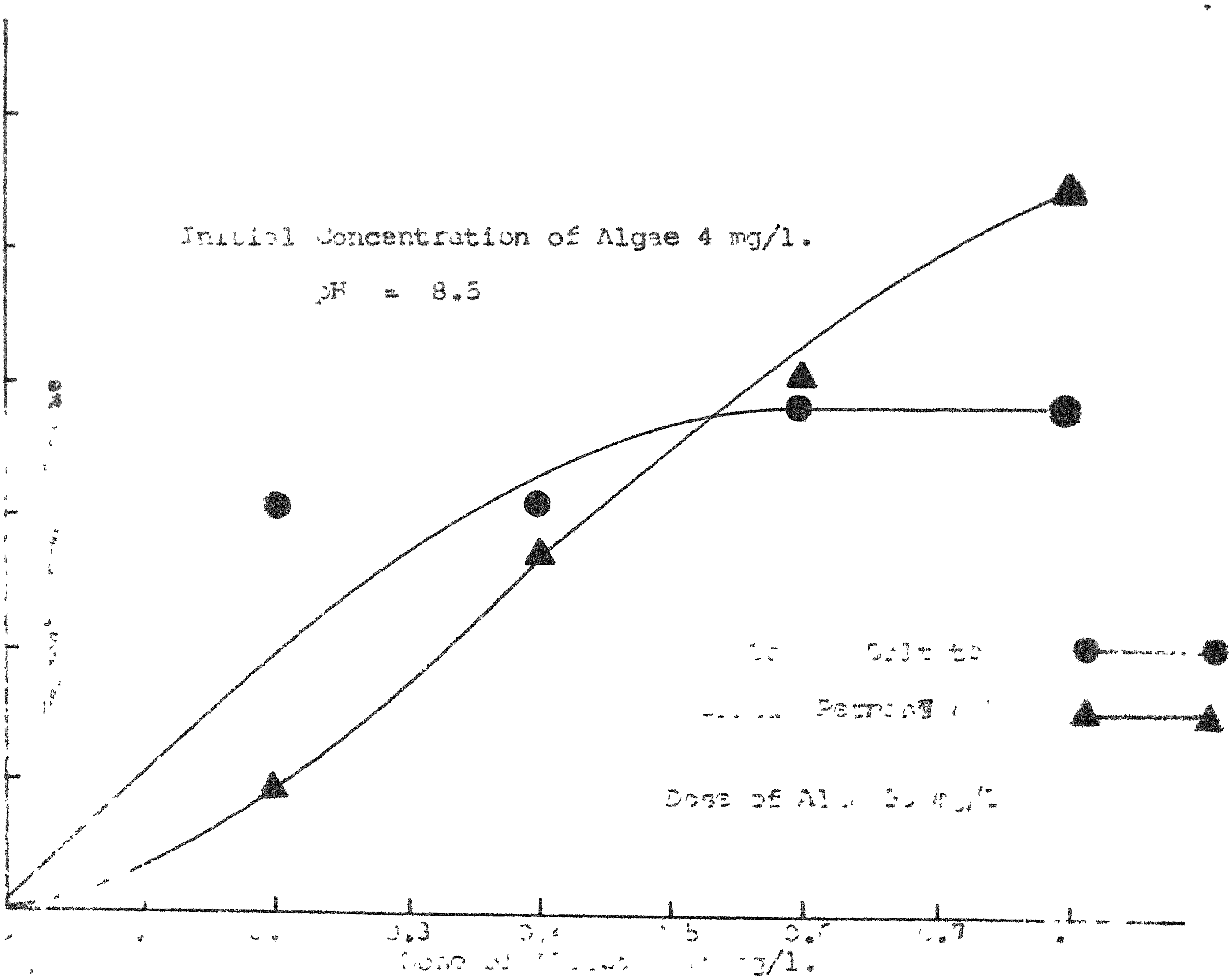


Figure 15

Removal of Low Concentration of Arthrospira dominating these ... Potassium Permanganate and Alum.

followed by sedimentation. In the second experiment 4 mg/l of potassium permanganate was applied contact time of 1 hour was given and then flocculation was done with different dosages of alum. Similar procedure was adopted with copper sulfate. The results are plotted in Fig. 16.

4.15 Effect of Copper Sulfate and Potassium Permanganate on Arthrospira Dominating Algae Removal

In these experiments effect of copper sulfate and potassium permanganate on the removal of Arthrospira was seen. Different dosages of copper sulfate varying 0 to 50 mg/l were applied and contact time of 1 hour was given. Flocculation was done with 200 mg/l of alum followed by sedimentation. Similar procedure was repeated with potassium permanganate. The results are shown in Fig. 17.

4.16 Effect of Lime and Animal Charcoal on Algae Removal (Arthrospira Dominating)

These experiments were conducted to find the effect of lime and animal charcoal on the removal of Arthrospira dominating samples. The doses of lime varying from 0 to 5000 mg/l were given. Contact time of 1 hour was provided and then flocculation was done with 200 mg/l of alum and then sedimentation followed. Similar procedure was adopted with animal charcoal. The results are shown in Fig. 18.

4.17 Effect of Conaact Time Given for Potassium Permanganate on Algae Removal (Arthrospiral Dominating)

In these experiments the effect of contact time for potasium permanganate on removal of Anthrospira dominating samples

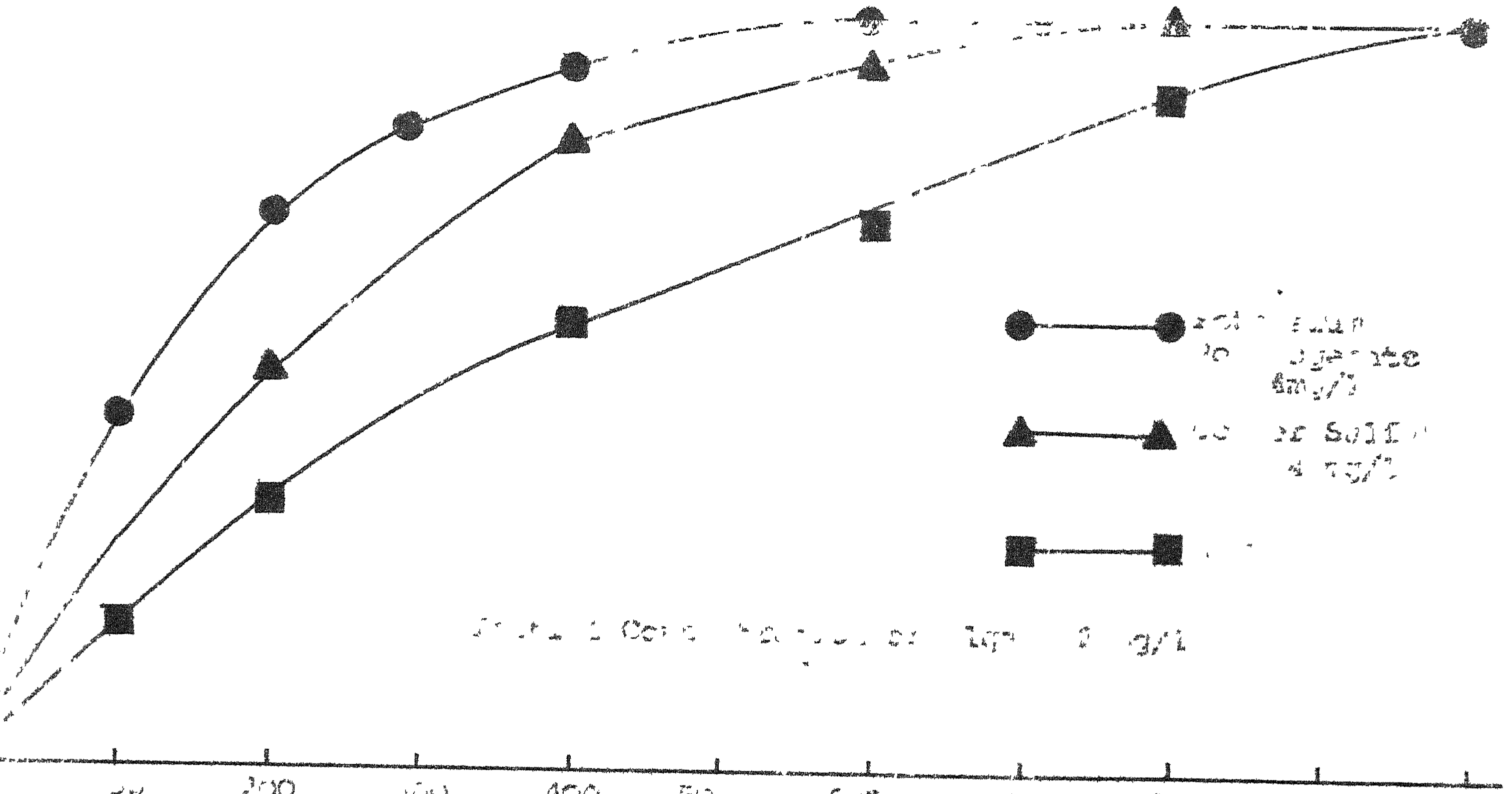


Figure 16

Fig 16. Effect of Algicides on Optimum Dose of Alum in case of Arthrospira dominating samples.

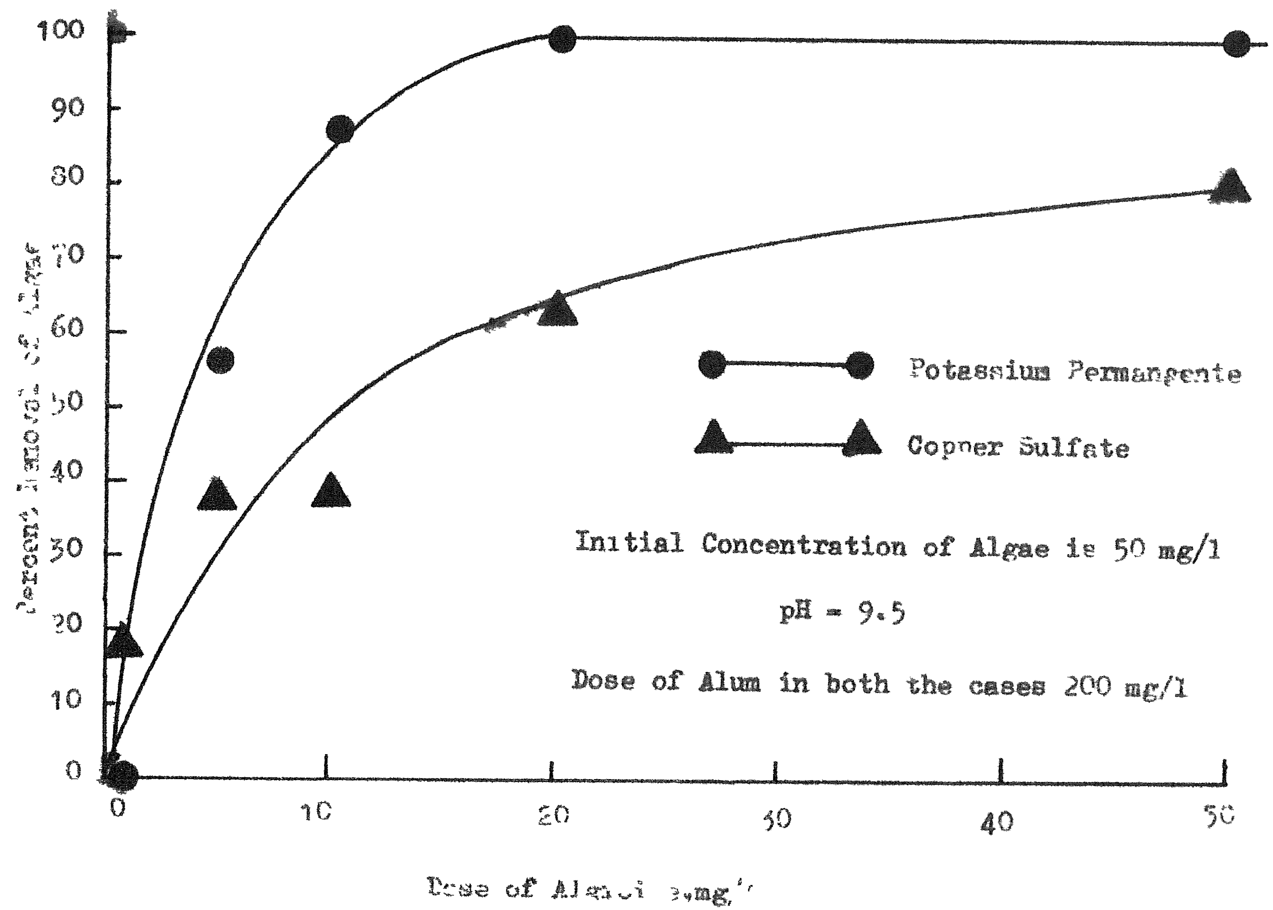
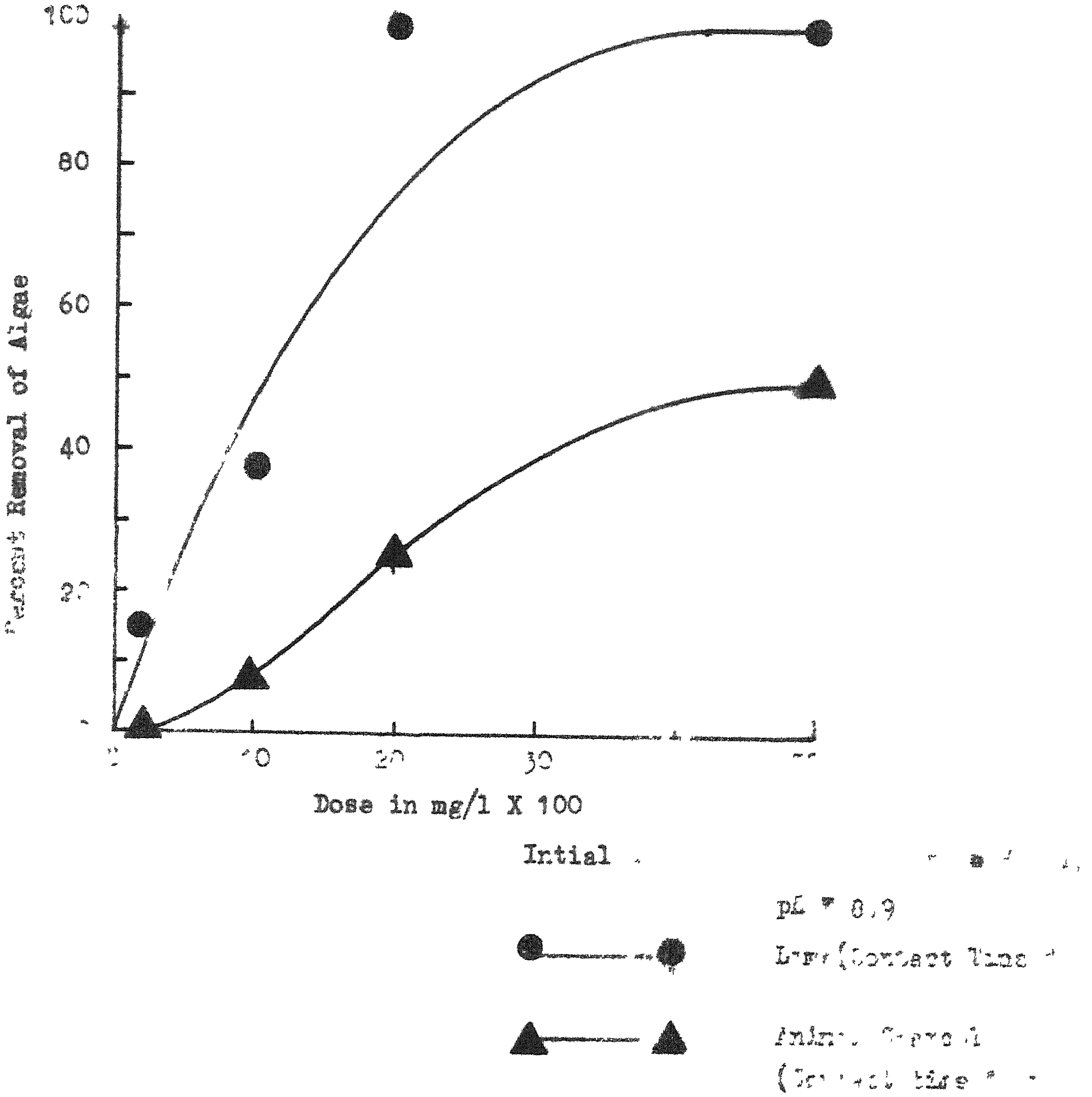


Fig .7. Effect of Copper Sulphate and Potassium Permanganate on Arthrospira dominating Algae removal.

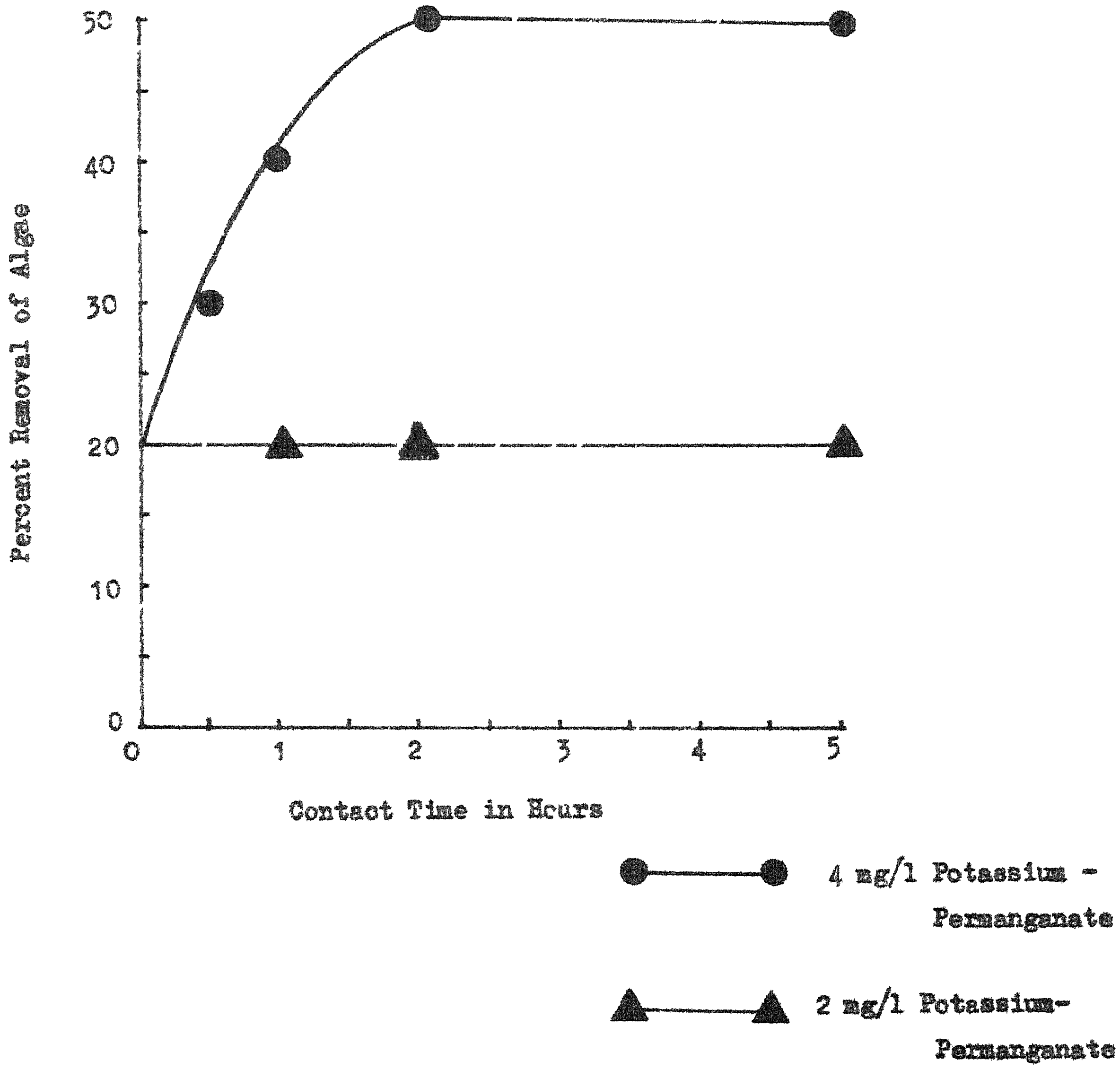

Percent Removal of Algae
100
80
60
40
10
30
Dose in mg/l X 100
Intial
pH = 8.9

was studied. In one case dose of 2 mg/l, and in other 0.5 mg/l of potassium permanganate was given. Contact time was varied from 0 to 5 hours. Flocculation was done with 200 mg/l of alum followed by sedimentation. The results are shown in Fig. 19.

4.18 Effect of Heat Treatment on Arthrospira Dominating Algae

The samples in which Arthrospira was dominating were taken in beakers and heated for ten minutes at temperatures varying from 43°C to 83°C. Then sedimentation was done for 1/2 hour. The results are shown in Fig. 20.

The discussion of the results, obtained from the experiments conducted, is given in the next chapter.



Initial Concentration of Algae = 36mg/l

pH = 8.9

Fig 19. Effect of Contact Time given for Potassium Permanganate on Algae Removal (Arthrospiral dominating)

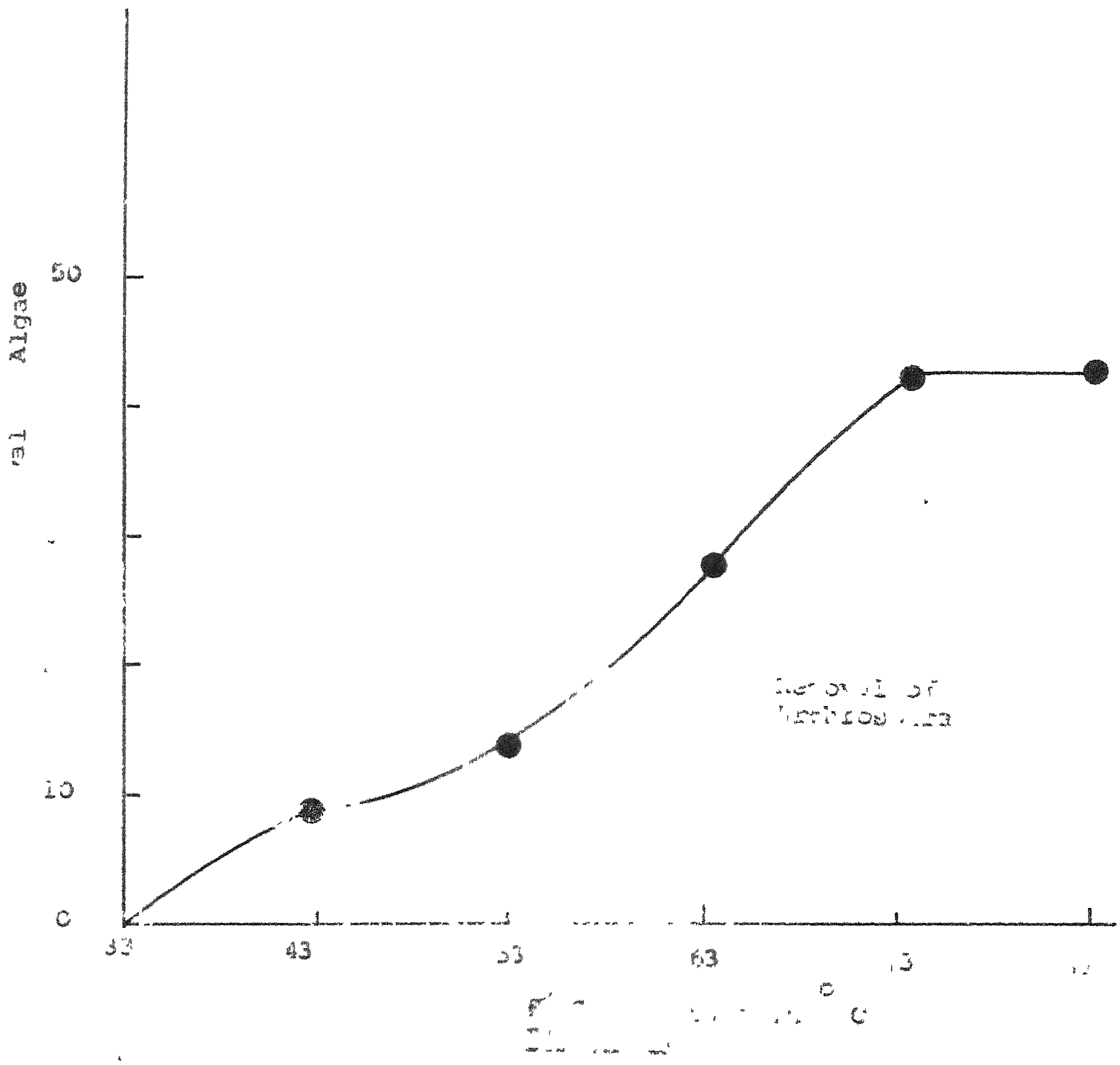


Fig 20. T... dominating Algae.

5. DISCUSSION OF RESULTS

The Figs. (5 to 7) indicate that when copper sulfate was used in concentrations of 1, 5 and 10 mg/l and 3 days time was given, it did not aid in removing chlorella. This supports that copper sulfate is ineffective against Chlorella as reported by Palmer (2).

Chlorine affected Chlorella. Almost 100 percent removal was obtained in three days at 5 and 10 mg/l dose, while only 66 percent removal occurred in three days at the dose of 1 mg/l. These results indicate that chlorine could be used in concentration of less than 5 mg/l for control of Chlorella provided longer contact times and sedimentation times are available (Fig. 5 to 7).

Of the three chemicals used potassium permanganate seems to be most promising for control of Chlorella in low concentrations. With 5 mg/l of potassium permanganate complete removal of Chlorella is obtained within 24 hours, even though 1 mg/l was not much effective for the same time. The use of potassium permanganate as an algicide for Chlorella was mentioned by Fitzgerald in the year , who was working with pure cultures of Chlorella to differentiate the algicidal and algistatic effect of chemicals. No other report could be found on the effect of potassium permanganate in natural water for control of Chlorella (Figs. 5 to 7).

It can be broadly concluded from above results that potassium permanganate is much better suited for the removal of algae specially when they are Chlorella.

The results shown in Fig. 8 indicate that copper sulfate even with 18 mg/l concentration removed less than 15 percent of Chlorella while potassium permanganate removed almost all the algae in 8 mg/l. This shows that copper sulfate does not aid removal of Chlorella while potassium permanganate enhances the removal.

Fig. 9 shows that only 9 percent removal was obtained with copper sulfate at the dose of 5 mg/l, while potassium permanganate gave 95 percent removal at the dose of 5 mg/l. This shows that copper sulfate did not aid in flocculation of Chlorella, but potassium permanganate aided flocculation. In the literature it is mentioned that potassium permanganate aids coagulation. The results obtained here support it.

All these results point to one thing, copper sulfate does not aid removal of Chlorella, hence the use of copper sulfate where Chlorella is dominating should be abandoned. The general tendency of waterworks people is to dump some amount of copper sulpate in water, whenever there is algae problem. The results obtained here show that copper sulfate, atleast, is a failure when Chlorella is dominating. When the dominating algae are Chlorella potassium permanganate should be applied to overcome the problem. Since potassium permanganate is a strong oxidizing agent and aids in coagulation author feels that potassium

permanganate may be the best solution to remove algae from water even when some other forms of algae are dominating.

In Fig. 10 and 11 the effect of contact time on algae removal is shown. In Fig. 10 the removal of algae is only 27 percent when potassium permanganate (2 mg/1) is added with alum i.e. when contact time given is zero but 73 percent removal is obtained when two hours contact time sis given. Fig. 11 also shows that removal is increased with time up to 2 hours. In Fig. 11 one other thing is also pointed out that when less dose (0.5 mg/1) of potassium permanganate is added the removal does not increase with time indicating that low doses of potassium permanganate are not enough for a reasonable removal of algae. Since contact time is of importance, to provide a required contact time, potassium permanganate may be added at the intake so that it will get certain contact time while it reaches waterworks. But if this time is very less the construction of basin to provide required contact time, before it enters the flocculation chambers is advisible. Where the water source is some reservoir and if it is not very large and used only as a source of water supply to provide a contact time is no problem, since potassium permanganate could be added to the reservoir itself. However if the capacity of reservoir is very large it is better to apply potassium permanganate at the intake rather than applying huge amounts to the whole reservoir.

Fig. 12 shows that 750 mg/l of alum is required for the complete removal of algae. Other conditions keeping similar when 1 mg/l of potassium permanganate is added and two hours contact time is given 100 percent removal is achieved with an alum dose of 400 mg/l. This indicates that the optimum dose of alum is reduced by the addition of 1 mg/l of potassium permanganate to 400 mg/l.

The optimum dose of ferric chloride required for 100% removal of algae was 550 mg/l (Fig. 13). This dose was reduced to 280 mg/l when 1 mg/l of potassium permanganate is added. This shows that potassium permanganate enhances the removal of Chlorella when flocculation is done.

From Figs. 12 and 13 it can be concluded that the addition of potassium permanganate reduces the coagulant dose.

The optimum dose of ferric chloride (550 mg/l) is lesser than the optimum dose of alum (800 mg/l) as can be seen from Fig. 12 and 13. This shows that ferric chloride is little more effective in removing Chlorella than alum. This may be because algae are inhibited at higher concentration of iron (2).

Tables 1 and 2 show the effect of chlorine on algae removal when flocculation is done. Removal of Chlorella was not much enhanced by chlorine even when doses up to 150 mg/l

were given. At the dose of 150 mg/l of chlorine, algae removal obtained was 41.3 percent showing that chlorine is not very effective in removing Chlorella. It was originally believed that nascent oxygen, produced by the reaction of chlorine with water, accomplished the destruction of bacteria. A plausible explanation is the theory that chlorine unites, at least in part, with the cell structure of the bacteria to form chloro-products that act as toxic poisons to bacteria, however, this may not be true in case of algae and since chlorine is less powerful oxidising agent compared to potassium permanganate it did not give appreciable results.

The effect of contact time allowed for chlorine to react with Chlorella is shown in Tables 3 and 4. Optimum contact time for 10 mg/l dose is 15 minutes while it is 30 minutes for 20 mg/l of chlorine. At the dose of 10 mg/l dose only 13 percent removal was obtained after 15 minutes while with 20 mg/l dose of chlorine after 15 minutes 21.8 percent was obtained and after thirty minutes the removal of algae obtained was 26.1 percent and then it remained constant for rest of the time indicating reaction of chlorine is fast.

Rie

Riehl et al (45) reported that by adding lime in sufficient amount to produce a pH value of 10.5 - 11.0 or even slightly higher, several benefits are obtained: an increased amount of magnesium is removed from the water; clarification is improved usually with less coagulent; and quite important

there is a pronounced bactericidal effect. On the other hand, there have been some observations of chemical attack on non-ferrous metal by the water at high pH levels.

No reference was found where lime was used for algae removal. The experiment shows (Table 5) that 100 percent removal of algae can be obtained by lime but the pH at that dose lime becomes very high. Hence, the use of lime for algae control does not have much practicability.

Since the activated carbon is used in many water works for the removal of taste and odor and also for algae control at some places, the experiment was conducted to see its effect on the Chlorella dominating water.

However, the experiment conducted (Table 7) did not give encouraging results. This shows that carbon cannot be separately as such used for algae control. It might give good results when coupled with other chemicals.

Black et al (46) reported that iodine has been shown to be extremely effective for the disinfection of two public water supplies. The physical and chemical properties of iodine make it particularly suitable for use as a water disinfectant. Because its vapor pressure is only 0.31 may be stored indefinitely in non-metallic containers and at atmospheric pressure without appreciable loss or deterioration. Although its water solubility is not high, its saturated solution is sufficiently concentrated for feeding purposes. Iodine's low chemical reactivity, least of all halogens, means that lower residuals are

only 75 percent removal was obtained with 50 mg/l of copper sulfate and 200 mg/l of alum. This shows that potassium permanganate is more effective compared to copper sulfate

Fig. 18 shows that almost 100 percent removal was obtained with lime at the dose of 2000 mg/l of lime and 200 mg/l of alum but the pH became 11.6. Hence the use of lime cannot be suggested. Animal charcoal did not give very encouraging results.

Fig. 19 shows that the reaction of potassium permanganate while reacting with algae is time dependent and the contact time plays an important role.

As can be seen from Fig. 20 heat treatment aids in removal of algae. The removal became almost constant from 73°C to 83°C.

The conclusions, drawn from the present study, are given in the next chapter.

6. CONCLUSIONS

1. Copper sulfate, the most widely and commonly used algicide, does not aid the removal of algae when they are Chlorella.

2. The removal of Chlorella dominating algae is enhanced by potassium permanganate.

3. Contact time required for potassium permanganate to react with algae plays an important role.

4. Optimum dose of coagulant is reduced by the addition of potassium permanganate.

5. Ferric chloride is more effective compared to alum in removing Chlorella by coagulation.

6. Though chlorine helps in removal of Chlorella dominating algae, it is not very effective compared to potassium permanganate. The time required for chlorine to react with algae is comparatively less.

7. Algae removal (Chlorella dominating) is enhanced by lime but the doses are such that pH becomes high. Same is true for Arthrospira dominating algae.

8. Animal charcoal was ineffective in removing Chlorella at low dosages, this applies to Arthrospira also.

9. The removal of Chlorella dominating algae is not aided by iodine.

10. Ulothrix could be controlled with potassium permanganate.

11. Potassium permanganate is more effective compared to copper sulfate in removing Arthrospira.

12. Removal of algae could be enhanced by heat treatment.

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